

# Clean Colorado River Alliance

## Recommendations to Address Colorado River Water Quality

January 2006







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## Acknowledgment

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Much appreciation goes to those members of the Clean Colorado River Alliance and other participants who traveled across Arizona to participate in meetings throughout 2005. A special “thank you” goes to those participants who diligently researched these issues and drafted this report. Much credit for this publication goes to Doyle Wilson of the Lake Havasu City staff, and to the excellent staff at the Arizona Department of Environmental Quality, including Susan Craig, Diana Marsh, and Melanie Ford of the Hydrologic Support and Assessment Section of the Water Quality Division, and to Phil Amorosi and Tom Marcinko of the Communications Department.



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## Executive Summary

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The Colorado River is one of the most significant rivers of the American Southwest, providing drinking water, power and irrigation for the states of Wyoming, Colorado, Utah, New Mexico, Arizona, Nevada and California and the country of Mexico. Its watershed area covers nearly 244,000 square miles of land. Many water quality issues threaten this vital western water source, and concerns about the potential environmental, social and economic impacts of River pollutants are growing as population in the Southwest increases exponentially.

In response to these growing concerns, in February 2005, Arizona Governor Janet Napolitano appointed a group of stakeholders, the Clean Colorado River Alliance, to produce an action plan to address water quality issues in the River. Governor Napolitano directed the Alliance to investigate water quality in the Colorado River and develop recommendations for protecting and improving the River, including regional approaches. The activities of the Alliance were coordinated by the Arizona Department of Environmental Quality (ADEQ).

### Pollutants of Concern

While a large number of water quality issues have the potential to impact the Colorado River, the Alliance identified several pollutants as being of particular concern in this effort: ***nutrients, metals, endocrine disrupting compounds, perchlorate, bacteria and pathogens, salinity/total dissolved solvents and sediment***. This report describes the impacts of these pollutants, discusses current mitigation efforts to address them, and sets forth a number of recommendations aimed at them.

#### ***Nutrients***

Industrial and municipal wastewater treatment facilities and landfills are potential point sources of nutrient pollution in the Colorado River. Potential nonpoint sources of nutrients include marinas, wastewater lagoons and other surface impoundments, irrigated agriculture, urban run-off, animal feed lots, septic tanks, fertilizer or manure applications to landscape, vehicle exhaust, atmospheric deposition and nitrogen fixation from natural processes. The impact of growth on wastewater treatment facilities coupled with aging infrastructure is of particular concern. Overloaded and aging treatment facilities can discharge significant quantities of nitrogen, including through overflows and leakage. Large numbers of septic tanks along the River especially contribute to the nitrate load of the shallow groundwater system that is hydrologically connected to the River. Excessive intake of nitrate can cause serious health effects. In infants, nitrate can reduce blood's ability to carry oxygen, resulting in asphyxiation, bluing of the skin (a condition known as "blue baby syndrome"), and potentially death. In others, nitrate has also been linked to increased rates of cancer, birth defects, miscarriage, reduced body growth and thyroid problems.

#### ***Metals***

A wide variety of sources and activities, both natural and man-made, and activities contribute to the presence of metals in the Colorado River. All surface waters contain metals, generally appearing in colloidal, particulate, and dissolved states. However, where these metals are present in water in more than very small quantities, there is a risk of adverse health and environmental effects. The Alliance has focused on four metals: ***selenium, chromium, mercury and uranium***. These metals threaten the Colorado River and can present serious health risks in humans and wildlife.

## ***Endocrine Disrupting Compounds***

Endocrine Disrupting Compounds (EDCs) have a wide variety of origins, both natural and synthetic, with the pharmaceutical and chemical industries leading the way in synthetics production. EDCs are often found in common household items, pesticides, and food and tobacco products. Additional research is necessary to characterize the occurrence of EDCs in the Colorado River and determine the impacts of exposure to EDCs on humans and ecosystems.

## ***Perchlorate***

Perchlorate was discovered in water supplies in the lower Colorado River in 1997. The contamination was traced to Lake Mead and the Las Vegas Wash, and eventually to a Kerr McGee Chemical Company (Kerr McGee) plant in Henderson, Nevada. This finding prompted US EPA, the Nevada Division of Environmental Protection (Nevada) and Kerr McGee to initiate efforts to control the source and reduce perchlorate releases to the Las Vegas Wash. The Alliance believes that appropriate containment, control and cleanup efforts are being implemented and are improving the concentrations and potential risk of perchlorate in and to the Colorado River. These ongoing efforts continue to reduce the low levels of perchlorate in the Colorado River. While it may take several years to achieve non-detect status (defined as less than 4 ppb), the current concentrations in the Colorado River are below current health standards and do not pose any threat to public health, provided that remedial activities continue.

## ***Bacteria and Pathogens***

Coliform bacteria are a large group of bacterial species and are most commonly associated with water quality. The two most likely pathogens that will be found in recreational waters are *Cryptosporidium* and *Giardia*. Potential causes of bacteria and pathogens in the Colorado River include the high density of on-site wastewater systems in River communities, storm water run-off during monsoons and other rain/storms events, and the inadequate number of sanitary facilities in recreational areas along the Colorado River. Bacterial contamination can result wherever there are high concentrations of people or animals.

## ***Salinity***

Increased salinity levels in the Colorado River affect agricultural, municipal and industrial users. Agricultural water users suffer economic damage due to reduced crop yields, added labor costs for irrigation management and added drainage requirements. Urban users must replace plumbing and water-using appliances more often, or spend money on water softeners or bottled water. Industrial users and water and wastewater treatment facilities incur reductions in the useful life of system facilities and equipment. Nearly half of the salinity in the Colorado River system is attributable to natural sources. Other potential sources of salinity in the Colorado River Basin include irrigated agriculture, energy exploration and development, and municipal and industrial facilities such as wastewater treatment plants. Treated wastewater is a source of salinity, so as population continues to increase in the Colorado River region, the amount of treated effluent will multiply, contributing to an increase in salinity.

## ***Sediment***

The Colorado River suffers from excess sediment in some areas of the watershed, and decreased sediment in others. Stream bank erosion, a natural source of sediment loading to the Colorado River, can be accelerated by human alteration of water flow and channel morphology. Dams, on the other hand, can decrease sediment below normal levels, altering wildlife habitat and causing the disappearance of natural sandbars and beaches.

## Recommendations

The Alliance submits the following recommendations for action by Governor Napolitano and other leaders to address and improve water quality in the Colorado River. In addition to the specific recommendations below, throughout this report the Alliance has called for increased public outreach and education efforts to enhance the public's awareness and understanding of water quality concerns in the Colorado River and ways to reduce the presence of pollutants in the River. Moreover, in the text of the report, the Alliance has identified potential funding sources that should be considered for the improvement of water quality in Colorado River and implementation of the Alliance's recommendations.

The Alliance recommends:

- Governor Napolitano should convene a summit of the Governors of the seven Basin States – Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming – to address the issue of water quality in the Colorado River.
- The water quality administrators of the seven Basin States should convene in advance of the Governors' summit to share existing information, identify water quality issues affecting the Colorado River that are not adequately addressed by existing institutions and regulations, coordinate an inventory of water quality concerns, develop a watershed-based, coordinated monitoring strategy, and develop an electronic repository of information related to Colorado River water quality. Follow-up meetings of the water quality administrators also should be held on a regular basis.
- Governor Napolitano and Arizona's congressional delegation should actively support the effort of the Colorado River Regional Sewer Coalition (CRRSCo) to obtain federal funding for wastewater infrastructure in communities along the River. The completion of wastewater infrastructure projects in River communities, such as Bullhead City and Lake Havasu, will help improve the quality of groundwater adjacent to the Colorado River and, ultimately, the River itself.
- Continued substantial financial support must be provided for wastewater infrastructure improvement projects adjacent to the River. Additional wastewater infrastructure improvement needs should be identified and potential locations of nitrate and bacterial contamination should be monitored. These identified needs should be prioritized based on contamination risk and expense.
- Governor Napolitano, ADEQ and other officials should closely monitor the potential water quality impacts of the proposal by the "Clean Water Coalition" in Nevada to discharge up to 450 million gallons per day of treated effluent from Las Vegas, Henderson and Clark County, Nevada, into Lake Mead, directly upstream of Hoover Dam.
- The investigation, monitoring and remediation of chromium contamination at both the Pacific Gas & Electric (PG&E) Compressor Station on the California side of the River at Topock (I-40 crossing) and at the former McCulloch manufacturing plant in Lake Havasu City in Arizona must continue. Officials must continue to require remediation of hexavalent chromium impacts to the groundwater system adjacent to the Colorado River and include hexavalent chromium analyses in all Colorado River water sampling programs.

- ADEQ should continue to monitor the U.S. Department of Energy's (DOE) plan to move the 12 million tons of radioactive uranium tailings at the Atlas Mill site near Moab, Utah, away from the Colorado River to a permanent disposal location 30 miles away at Crescent Junction, Utah, and press DOE to move the tailings as quickly as possible. Governor Napolitano and ADEQ also should continue to press DOE to ensure that DOE conducts active remediation of contaminated groundwater at the Moab site and prevent further releases of contaminated groundwater into the Colorado River.
- ADEQ and other agencies should conduct a coordinated effort to identify and investigate abandoned mines and other potential sources of mercury and other metals along the River, including surveying and sampling to detect areas with existing metals contamination. ADEQ also should seek additional air deposition monitoring stations in Arizona to help assess the impact of airborne mercury emissions on mercury levels in the Colorado River.
- Governor Napolitano and Arizona's congressional delegation should support full federal funding of salinity control projects implemented under the Colorado River Basin Salinity Control Act. Salinity control projects funded under Title II of the Act have served to reduce the total salt load on the River (with the added benefit of reducing the metal selenium). The Colorado River Basin Salinity Control Forum has set a goal of 1 million tons of additional salt removal by the year 2020. While most of the new salinity controls will be implemented in the Upper Basin states, they will improve water quality throughout the Colorado River. Further, any National Pollutant Discharge Elimination System (NPDES) or Arizona Pollutant Discharge Elimination System (AZPDES) permits authorizing surface water discharges to the Colorado River should be consistent with Colorado River Basin Salinity Control Forum policy.
- In coordination with designated planning agencies, ADEQ should review and establish a process to adjust, if necessary, the regional water quality management planning program in regard to wastewater planning along the Colorado River. The review should include planning for discharge locations, wastewater facility design, adequate treatment and disposal capacities and methods and effluent water quality. ADEQ also should make certain that all new sewage treatment facilities meet performance requirements and that existing facilities are upgraded to meet best available demonstrated control technology standards.
- ADEQ, the Arizona Department of Water Resources (ADWR) and other appropriate agencies should develop coordinated monitoring activities to determine trends of selenium concentrations in the Colorado River and in target species in the River. ADEQ also should regularly monitor fish tissue for selenium concentrations in the River.
- ADEQ should work with relevant entities, including universities, to compile and assess data on the potential impacts of endocrine disrupting compounds in the River.
- ADEQ should continue to monitor the ongoing remediation and mitigation efforts at the Kerr McGee facility in Nevada to ensure that perchlorate levels in the Colorado River continue to decline.

- ADEQ should work with other appropriate state, local and federal agencies and stakeholders to develop a data gathering and monitoring network to identify “hot spots” for bacterial contamination in the Colorado River, including conducting a concentrated survey along the River at high use areas and during busy seasonal periods.
- State and local agencies should conduct aggressive education and outreach efforts to promote the use of best management practices to address soil erosion and sedimentation, reduce urban and construction run-off and decrease the use of off-road vehicles in sensitive areas in order to reduce levels of sediment in the Colorado River.





# Chapter 1

## Introduction

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## Chapter 1 - Introduction

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In February, 2005, Arizona Governor Janet Napolitano asked a group of key stakeholders in the state to develop recommendations to address existing water quality problems and assist her in working with fellow states towards solutions for improving Colorado River water quality (see Appendix 1). In her letter, Governor Napolitano states the following:

*"The Colorado River serves as the lifeblood of the American West providing drinking water to more than 25 million people and irrigation water to support 2 million acres of agricultural production. For years the focus of the Colorado has been on water quantity and indeed, I will continue to fight to secure our share of this critical resource. However, we can no longer focus on water quantity alone, we must address water quality as well if we are to truly meet the needs of the state.*

*There are several major issues currently threatening the quality of water in the Colorado River. Unfortunately, the problems tend to accumulate with movement downstream, and Arizona is the last State to divert flows from the Colorado before it crosses into Mexico. While many of the problems manifest themselves most severely in Arizona due to geographic location, the problems are, in fact, regional issues and cannot be tackled on solely a state level.*

*Effectively cleaning up the Colorado River will require a regional approach involving federal, state, tribal and local governments as well as other key stakeholders including agricultural, municipal, business and conservation sectors. Therefore, I have decided to name a stakeholder group, the Clean Colorado River Alliance (CCRA), to develop recommendations to address existing water quality problems."*

### Clean Colorado River Alliance Mission

*Develop recommendations to address existing water quality issues to ensure Colorado River water quality meets the needs of Arizona now and in the future.*

## ***Objectives***

The goals of the Alliance include:

- Develop a plan to create a regional approach to address Colorado River water quality issues
- Document and prioritize water quality improvement projects to be implemented (short-term and long-term)
- Document funding needs and sources and identify processes to secure funding
- Develop an action plan to secure and direct funding and implement identified water quality improvement projects

## ***Approach***

Joined by Governor Janet Napolitano in April 2005, the Alliance met for the first time to discuss the mission and the timeline for completion of this report. From April to December, the Alliance met five times at locations throughout Arizona. Meeting notes from each of the meetings and other items of information are on the CCRA Web site: [www.azdeq.gov/envIRON/water/ccra.html](http://www.azdeq.gov/envIRON/water/ccra.html).

First, the Alliance identified pollutants of concern (see the draft pollutant list – Appendix 2) and then developed eight criteria for deciding and prioritizing which pollutants the Alliance would address in the report. The criteria are listed below in no particular order of importance:

- “Current problem, exceed/violate water quality standards and number of locations” and “instances the pollutant exceeds standards”
- “Public/aesthetic consideration” or “public perception”
- “Causing or anticipated to pose human or ecosystem health concern” and “acute risk of public and/or environmental risk”
- “Clearly defined location of pollutant removal”
- “Identified sources”
- “Hard data, i.e. monitoring threshold”
- “Quantity of pollutant or threat/risk”
- “Upward trend”

After developing the criteria and voting, the Alliance decided to address seven pollutants. In order, based on the number of votes, the following pollutants were selected:

1. Nutrients (nitrogen, nitrates, ammonia, phosphorus)

2. Metals (chromium, uranium, copper, mercury, arsenic)

Note: The metals originally selected were evaluated on June 17, 2005 and on October 21, 2005, the Alliance decided to change the focus on: selenium, chromium, mercury and uranium.

3. Endocrine disrupting compounds

4. Perchlorate

5. Bacteria/pathogens

6. Salinity/total dissolved solids

7. Sediment/turbidity

Pollutant workgroups were established (Appendix 3) and each workgroup was responsible for drafting a pollutant chapter of the report.

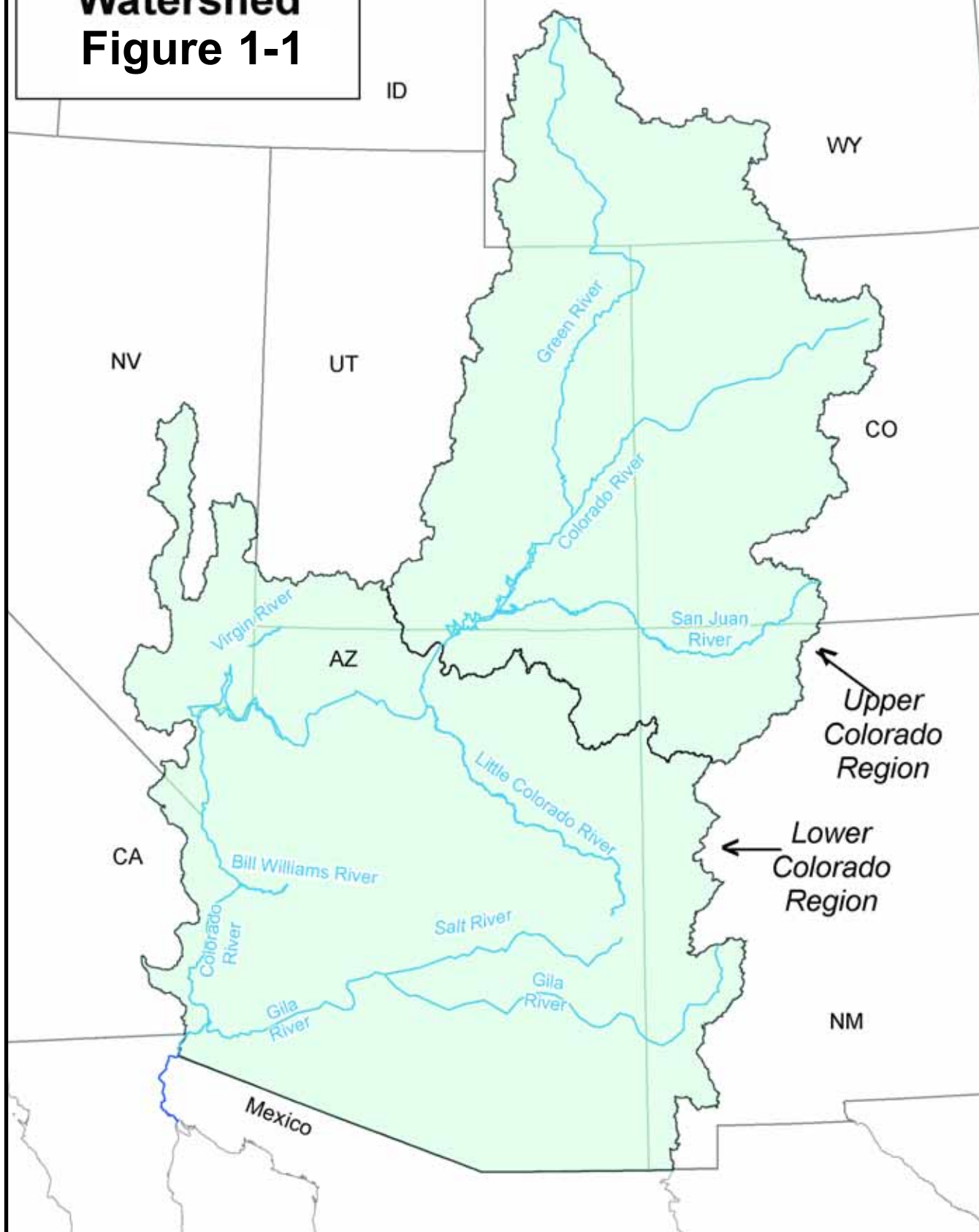
### ***Colorado River Watershed & Water Quality***

The 244,000 square mile Colorado River Watershed stretches from the mountains of Colorado and Wyoming south and west through the states of Utah, New Mexico, Arizona, Nevada, and California. Crossing into Mexico (see Figure 1-1, page 13), the watershed encompasses parts of Sonora and Baja California. About 85 percent of the Colorado's water originates in the mountains of Colorado, yet communities and ecosystems as far south as Mexico rely on its flow. More than 25 million people depend on its water for drinking and irrigation. "The river irrigates 1.8 million acres of land, producing 15 percent of U.S. crops and over 80 percent of the winter vegetables consumed in the United States are grown with its water." (Project WET International, 2005).

Throughout this report agriculture is often mentioned as a potential source of water quality problems. However, Arizona agriculture is at the "bottom" of the Colorado River system. According to the 2004 Arizona Agricultural Statistics Bulletin, issued September 2005 and published by the United States Department of Agriculture, 339,550 acres were harvested in 2004 in the Colorado River counties of Mohave, La Paz, and Yuma. Accordingly, approximately 17% of the total acres irrigated by the Colorado River are in Arizona. Notably, Arizona and its agencies have enacted laws and regulations to minimize or eliminate and monitor Arizona agriculture's impact on river water quality.

The Colorado River enters Arizona at Lake Powell, flows through the Grand Canyon National Park, and leaves the state at the Mexico border near Yuma. As shown in Figure 1-1, the entire state of Arizona can be considered part of the Colorado River drainage. However, the focus of this report was on the main stem of the Colorado River along the western boundary of the state (see Figure 1-1, page 13). The Colorado River Watershed in Arizona contains spectacular incised canyons formed by erosion of sedimentary formations (e.g., sandstone), as well as volcanically formed mountains and high plateaus. Except for Kingman, Williams, and communities along the lower Colorado River (Yuma, Bullhead City, Lake Havasu City), most of this 30,896 square mile watershed is sparsely populated with only 255,200 people (2000 census).

# Colorado River Watershed Figure 1-1



The Grand Canyon National Park, Kaibab National Forest, Lake Mead National Recreation Area, and Glen Canyon National Recreation Area are all located within the watershed. Six wildlife refuges and three wilderness areas have been established in this watershed, along with several military bases with live-fire exercise areas. All of these have restricted land uses.

In Arizona, elevation in the Colorado River Watershed ranges from 10,400 feet above sea level near Flagstaff to 80 feet above sea level along the Colorado River as it enters Mexico. The area contains high and low desert fauna and flora and includes coldwater and warmwater aquatic communities where perennial waters exist.

Portions of the Colorado River Watershed in Arizona are impaired (not attaining water quality standards under the Clean Water Act) due to copper, *Escherichia coli*, boron, selenium and suspended sediment concentration, boron, DDT metabolites, toxaphene and chlordane in fish tissue, and dissolved oxygen. A full description of these and other water quality impairments can be found in Arizona's 2004 Integrated 305(b) Assessment and 303(d) Listing Report.

Other known issues in the Colorado River Watershed include: nitrogen or nitrates, chromium, uranium, perchlorate, and bacteria. These pollutants are discussed below in Chapters 2 through 8.

### **Economic and Environmental Sectors Impacted\***

Water quality impacts broad areas of Arizona's economy and environment. The following sectors of Arizona's economy and environment are vulnerable to impacts from poor water quality:

- Irrigated Agriculture
- Municipal and Industrial Water Users
- Public Health
- Aquatic Life
- Livestock and Wildlife
- Environmental Health and Watershed Management
- Commerce and Recreation
- Tourism

Water quality is vital to business and industry, wetlands and forests, energy producers, fish and wildlife, recreation, and agriculture. The Colorado River and its tributaries carry the water that makes life possible in the arid southwestern United States and northwestern Mexico. The river and its tributaries are essential to the functioning of diverse ecosystems, communities, and economies throughout a vast region. General economic and environmental sectors and potential impacts are identified in Table 1-1.

**Table 1-1: Economic and Environmental Sectors and Potential Water Quality Impacts**

Sector	Potential Impacts of Poor or Reduced Water Quality
Irrigated Agriculture	<ul style="list-style-type: none"> <li>• Reduced agricultural production</li> <li>• Crop damage</li> <li>• Increased pest outbreaks</li> <li>• Increased water supply costs</li> <li>• Increased management applications (fertilizer, herbicides, pesticides)</li> <li>• Problems with soil structure, infiltration, and permeability and aeration rates</li> </ul>
Municipal and Industrial Water Users	<ul style="list-style-type: none"> <li>• Damage to pipes, fixtures, and appliances</li> <li>• Disrupted filtration and treatment processes</li> <li>• Unpalatable mineral tastes</li> <li>• Additional treatment</li> <li>• Higher costs for treatment</li> <li>• Reduced quality water supplies</li> </ul>
Public Health	<ul style="list-style-type: none"> <li>• Increased illnesses and metabolic and hormonal dysfunction</li> <li>• Increased potential of disease transmission</li> <li>• Physiological effects</li> </ul>
Aquatic Life	<ul style="list-style-type: none"> <li>• Decline in native fish and aquatic life populations</li> <li>• Fish kills</li> <li>• Reduced growth rates</li> <li>• Decreased resistance to disease</li> <li>• Modification of natural migration and predation</li> </ul>
Livestock and Wildlife	<ul style="list-style-type: none"> <li>• Increased illnesses and mortality rates</li> <li>• Increased supplemental watering costs</li> <li>• Increased disease outbreaks</li> <li>• Reductions in herd size</li> </ul>
Environmental Health and Watershed Management	<ul style="list-style-type: none"> <li>• Reduction in forage production</li> <li>• Reduction in riparian habitat</li> <li>• Increased groundwater contamination</li> </ul>
Commerce and Recreation	<ul style="list-style-type: none"> <li>• Increased risk to swimmers</li> <li>• Recreation closures</li> <li>• Reduced sales and use of outdoor recreation equipment</li> <li>• Reduction in rural recreation economy</li> <li>• Reduced migration of new businesses</li> </ul>
Tourism	<ul style="list-style-type: none"> <li>• Reduced visitations to parks</li> <li>• Decreased number of winter visitors</li> <li>• Decrease in conventions and hospitality events</li> </ul>

\*Portions of this section are based on the Arizona Drought Preparedness Plan - Background & Impact Assessment Section.

In Chapters 2 through 8, water quality impacts from each pollutant addressed by the Alliance are described in more detail.

In each of the following chapters, the Alliance makes a number of recommendations regarding the specific pollutant(s) discussed therein. The Alliance points out, however, that the recommendations for a specific pollutant should not be viewed in isolation from recommendations elsewhere in this Report, and instead should be seen as part of an overall strategy for dealing with water quality issues in the Colorado River. In fact, some recommendations address more than one pollutant and are set forth in more than one chapter.

By the same token, while this report and the recommendations herein are addressed primarily to Governor Napolitano and Arizona policymakers, the problems facing the Colorado River are, as the Governor stated in her February 2005 charge to the Alliance, “regional issues and cannot be tackled on solely a state level.”

Accordingly, in addition to the recommendations regarding specific pollutants, the Alliance recommends that Governor Napolitano convene a summit of the Governors of the seven Basin States – Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming – to address the issue of water quality in the Colorado River. The involvement and cooperation of the other Basin States is essential to developing a successful long-range strategy for protecting and improving water quality in the Colorado River. This report can serve as a framework for the issues to be discussed at such a summit.

To ensure the Basin States’ Governors summit is as productive as possible, the Alliance further recommends that the water quality administrators of the seven Basin States convene in advance of the summit to share existing information, identify water quality issues affecting the Colorado River that are not adequately addressed by existing institutions and regulations, coordinate an inventory of water quality concerns, develop a watershed-based, coordinated monitoring strategy, and develop an electronic repository of information related to Colorado River water quality. This work will lay a strong foundation for a meeting of the Governors and help them tackle the issues affecting water quality in the River in a meaningful way. Similarly, follow-up meetings of the water quality administrators also should be held on a regular basis to ensure that work on Colorado River water quality issues moves forward with the coordination and collaboration of all the Basin States.



## Chapter 2

### Nutrients

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### Pollutant Description of Nutrients

Nutrients are a special group of chemical elements and compounds that supply plants with the necessary potential energy that is utilized during metabolic processes, along with sunlight, to convert carbon from carbon dioxide into organic carbon compounds. Important nutrients such as compounds of carbon, nitrogen, phosphorus, and sulfur are common at some concentration in the environment. Phosphorus, organic carbon, and sulfur do not pose direct health concerns, yet concentrations above 1.0 mg/l of mobile ortho-phosphate compounds in the aquatic environment can lead to algal blooms, which lead to low dissolved oxygen levels and fish kills when dead algae decompose. Concentrations of phosphate approaching 1.0 mg/l in surface and ground water are generally absent in the Lower Colorado River system. Among the U.S. Environmental Protection Agency (EPA) and the three states bordering the lower Colorado River, only Nevada's Department of Conservation and Natural Resources has mandated water quality standards in Lake Mead and along the Colorado River for phosphate (0.05 mg/l).

Arizona Department of Environmental Quality (ADEQ), U. S. Geological Survey, and U. S. Fish and Wildlife Service water analyses for phosphate over the past 15 years on the Colorado River main stem and the Bill Williams River have yielded up to 0.7mg/l in the Bill Williams River and up to 0.45 mg/l in the Colorado River above Diamond Creek in the Grand Canyon. Phosphate concentrations on the main stem between Lake Mead and Morelos Dam north of Yuma have been consistently below 0.1 mg/l.

Organic carbon and sulfur, usually as sulfate, are generally found at modest quantities in surface and ground water along the River system, although a few samples have yielded sulfate at levels above its 250 mg/l secondary Maximum Concentration Level (MCL) for safe drinking water. The secondary MCL is a non-enforceable aesthetics-based guideline of the federal Safe Drinking Water Act. Total organic carbon levels measured in the Colorado River by the Central Arizona Water Conservation District and other surface water users generally have been less than 10mg/l, but may have higher concentrations during flooding events. There are no direct federal regulations in place on its concentration, yet dissolved organic carbon compounds in surface water may react with chlorine-based disinfectants to yield trihalomethane and haloacetic acid by-products, which are regulated by the EPA.

#### **Role of Nitrogen**

Nutrients like nitrogen are necessary for healthy waters, but high levels of nutrients can cause a number of problems, ranging from nuisance algae blooms and cloudy water to threatening drinking water and harming aquatic life.

Nitrogen can exist in several forms (i.e. nitrate, nitrite, organic nitrogen, and ammonia nitrogen), two of which, nitrite and nitrate, are harmful to humans, livestock and wildlife when present in sufficient quantities. Both forms may pose a potential health threat. In addition to causing deleterious health effects on humans and livestock, elevated concentrations of nitrogen (and phosphorus) can cause eutrophication of receiving streams and

lakes. Elevated concentrations of nitrate can also be accompanied by higher than normal counts of fecal-indicator bacteria, which may indicate the presence of pathogenic bacteria, viruses, and protozoa. Since nitrate impacts are more widespread than other forms of nitrogen, the following sections are dedicated to a summary description of nitrates, their potential sources, their influence along the lower Colorado River, and mitigation efforts to minimize nitrate concentrations in the aquatic environment.

Nitrogen gas composes 78% of the earth's atmosphere in the form of  $N_2$ , which is converted or fixed to either an oxygenated compound like nitrate ( $NO_3$ ) or nitrite ( $NO_2$ ), a hydrogen compound like ammonia ( $NH_3$ ), or a nitrogen-bearing organic compound, by plants, natural atmospheric processes (lightning), or by industrial processes. The nitrogen cycle in nature includes the fixation of nitrogen by plants and the atmosphere into the above mentioned compounds and denitrification (a series of chemical reactions to reduce nitrogen) back to nitrogen gas into the atmosphere via bacterial metabolic processes. This cycle has been altered on a global basis with the advent of agriculture and industrial manufacturing.

Nitrogen in surface or ground water can be reported in terms of total nitrogen, nitrate-nitrogen, nitrite-nitrogen, ammonia nitrogen, and Kjeldahl nitrogen (the sum of organic and ammonia nitrogen). The last two nitrogen forms are important as indicators of nearby organic sources such as septic tanks where microorganisms produce ammonia while decomposing organic matter. Ammonia is highly mobile and is easily oxidized so that ammonia levels far away from the source are usually low in groundwater. Nitrites, usually an intermediate product of ammonia oxidation, also are oxidized when exposed to aerobic groundwater and are converted rapidly to nitrates. Nitrite levels are usually low in the groundwater system, but may be elevated near organic sources. Chemically, nitrates are soluble in groundwater and are very mobile, traveling far from their source. They may persist in surface water if high enough levels are brought to the surface in sufficient quantities.

## Sources

In pristine natural environments, free nitrogenous compounds such as ammonia, nitrite and nitrate are extremely scarce, virtually all the available nitrogen is 'locked away' as plant or animal protein. But today, even natural environments, such as lakes or rivers can be affected by high levels of ammonia, nitrite or nitrate.

Potential sources for nitrates in the Colorado River and adjacent shallow groundwater may be grouped into point sources (places that can be specifically identified) such as industrial and municipal wastewater treatment facilities and landfills, or as non-point sources (broad areas of impact) such as marinas, wastewater lagoons and other surface impoundments, irrigated agriculture, urban run-off, animal feeding operations, septic tanks, fertilizer or manure applications to landscape, vehicle exhaust, atmospheric deposition, and nitrogen fixation from natural processes. Nitrates are also found in uncooked and cooked vegetables and nitrites in cured meats, but in much greater concentrations.

The impact of growth on wastewater treatment facilities coupled with aging infrastructure is of particular concern. Overloaded treatment facilities, even those that include treatment processes specifically designed to remove nutrients can discharge significant quantities of

nitrogen to surface waters. Effectuated surface impoundments like percolation ponds, can contribute large quantities of nitrogen to groundwater. Aging infrastructure can contribute nitrogen to both ground and surface water through Sanitary Sewer Overflows (SSO) and leakage.

Large numbers of septic tanks along the River, both in rural and semi-urban areas, contribute to the nitrate load of the shallow groundwater system that is hydrologically connected to the River. Lake Havasu City, Bullhead City, Parker, and smaller communities along the River either have or have had high septic tank densities where the potential for nitrate influx into the River system is high. Effluent from a septic tank system can have a total nitrogen content of 25 to 60 mg/l, most of which is ammonia and less than 1% is nitrate. Ammonia is rapidly oxidized in the leach fields, however, producing significant quantities of nitrate. Nitrates will migrate in groundwater and enter drinking water wells down slope that are tapping the same aquifer, which leads to consumption (Figure 2-1).

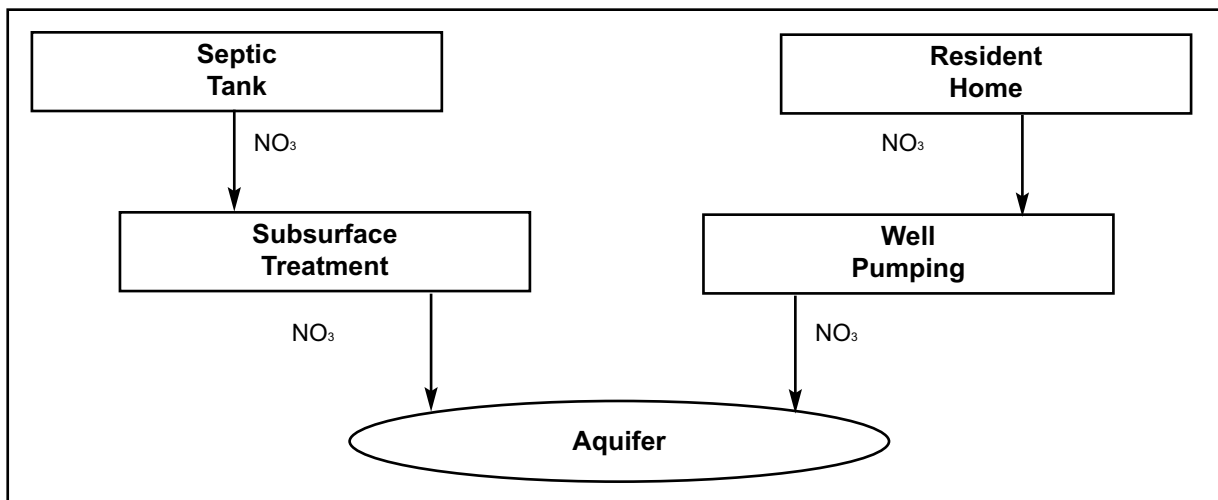


Figure 2-1: Potential nitrate pathway in a domestic water use system.

Agriculture along the Colorado River in Mohave County occurs in Mohave Valley, north of Topock to Bullhead City. Southward along the River agriculture is more widespread in La Paz and Yuma counties in Arizona and San Bernardino, Riverside, and Imperial counties in California. ADEQ studies in the 1990s along the river from Mohave Valley to Yuma found nitrate concentrations as high as 122 mg/l in well water from agricultural sources adjacent to the River. Fertilizer and pesticide applications as well as decomposing organic matter (unused crops, animal feed grains, and manure from farm animals) may contribute nitrogen in the form of nitrates that percolate to the shallow groundwater system, which is connected to the River, and that are caught in runoff directly to the River during precipitation events and/or continuously from drainage ditches.

The California Regional Water Quality Board's Colorado River Basin Region is placing a strong emphasis on surface and groundwater monitoring and protection. One of their high priority issues from the 2004 Triennial Review is to develop guidelines for sewage disposal from land developments. The Regional Board currently only regulates approximately 3,000 of 28,000 systems known to be in existence.

Effluent from percolation ponds or infiltration beds at wastewater treatment plants is a source of a certain amount of nitrate to the subsurface that migrates to the River system. Cities that dispose effluent in this way include Lake Havasu City, Bullhead City, and Blythe, California. Some facilities such as at Las Vegas and Laughlin, Nevada, Needles, California, Quartzite and Yuma, Arizona, and St. George, Utah have obtained variations of the NEPES permit to dispose treated effluent directly into the Colorado River System.

Las Vegas releases A+ treated effluent into Las Vegas Wash, part of which has been transformed into a wetland filtering system. The water eventually flows into Lake Mead. Two Nevada cities (Las Vegas and Henderson) and Clark County, Nevada (the "Clean Water Coalition") also have proposed to discharge up to 450 million gallons per day of treated effluent directly into Lake Mead. St. George's treated waste water is disposed into the Virgin River, which also empties into Lake Mead. The permits for disposal include regulations to keep nitrate concentrations as low as possible and always below the EPA's 10 mg/l MCL. These plants may also distribute the effluent for irrigation to golf courses and other landscape properties where nitrates may undergo fixation to organic nitrogen compounds.

Landfills, if unlined or not lined properly, can also be a source of ammonia-nitrogen from decomposing organic matter, such as food spoils, which, under oxidizing conditions is, converted to nitrate. Landfills such as those at Lake Havasu City, Mohave Valley, Needles, and Quartzite occur adjacent to the Colorado River, but their affect on the River system with respect to nitrates is not currently known.

Fertilizers have application beyond agricultural practices. They are used for landscape activities, such as keeping grass green for golf courses, ball fields and municipal/commercial/school/ government landscaping. Heavy applications can lead to elevated levels of nitrates in shallow groundwater that are not consumed by plants.

Ammonia-nitrogen associated with the uranium tailings near Moab, Utah also threatens Colorado River water quality. Ammonia concentrations near the source may be as high 2 mg/l, which is dangerous to fish and other aquatic life in the river. Local fish kills may result at and just downstream from the source. The threat decreases downstream as the ammonia oxidizes into nitrates in the River.

Recreation along the River, including boating and camping, contributes relatively small, dispersed quantities of human waste, yet increased recreation use through population growth will lead to greater impacts on the aquatic system.

A natural potential source of nitrates in the surface and ground water systems in the desert Southwest is from the subsoils or alluvium (gravel and sand) covering the bedrock of the mountains adjacent to the River. This source may be only significant during very wet years when the alluvium is thoroughly saturated and nitrates are leached into the shallow groundwater system. Nitrate salts blown from playa lakes further west may be picked up into the atmosphere by high winds and deposited in the region. These salts are carried into the subsoil and accumulate until a period of water saturation leaches the nitrates into mobile form and they are carried down slope in shallow groundwater or by surface runoff. This hypothesis is supported by regional studies that have detected elevated nitrate levels in subsoils of the Mojave and Sonoran deserts. Studies at the City of Tucson's Sweetwater surface recharge facility also indicate residual nitrates unused by plant roots in the vadose zone are mobilized by infiltrating water.



## **Water Quality Impacts**

### **Health Concerns**

Health impacts from consumption of high nitrate-bearing water mostly involve infants less than six months old. Children this young have not yet developed the hydrochloric stomach acid used to help digest food. The lack of acid and the abundance of nitrate in the stomach act to support nitrate-reducing bacteria that convert nitrate to nitrite, which combines with hemoglobin in the blood stream to form methemoglobin. This substance cannot carry enough oxygen to the rest of the body, resulting in asphyxiation, a chocolate brown color to the blood, and bluing of the skin (a condition known as “blue baby syndrome”), and eventually could lead to death. Pregnant women, adults with reduced stomach acid, and people deficient in the enzyme that changes methemoglobin back to normal hemoglobin are also at risk in developing nitrite-induced methemoglobin. Nitrates are metabolized in the body and passed through the system without being reduced to nitrites. Nitrate has also been tentatively linked to increased rates of stomach cancer, birth defects, miscarriage, leukemia, Non-Hodgkin's lymphoma, reduced body growth, slower reflexes and increased thyroid size. Prolonged exposure to very high nitrate levels can produce gastric problems and even cancer in laboratory animals.

Nitrites are generally worrisome for all children because they can interact with other substances in the body to form a potential cancer-causing chemical called nitrosamine. Livestock and wildlife are also susceptible to the same nitrite and nitrate toxicity. Young cattle and sheep, including desert bighorn sheep, are especially vulnerable as are all ages of horses, yet their tolerated consumption levels are about ten fold above those for humans.

### **Ecological Concerns**

In addition to its health effects on humans, nitrates have significant impacts on waterbodies. Eutrophication is the natural aging process of lakes and rivers. As these waterbodies become better nourished with the input of nutrients and sediment through erosion and precipitation, they gradually become shallower, warmer and more biologically active.

The aging process is accelerated when high levels of nitrogen found in untreated or poorly treated residential, municipal and industrial wastewaters is discharged to the River. The excess nitrogen over stimulates the growth of aquatic weeds and algae. Excessive growth of these types of organisms consequently clogs waterways. Algal blooms block light to deeper waters and deplete dissolved oxygen as they decompose. This proves very harmful to aquatic organisms as it affects the respiration ability of fish and other invertebrates that reside in water. Fish kills as well as changes in the types and numbers of aquatic species are not uncommon in lakes and rivers where eutrophication is accelerated by such discharges. Ultimately, eutrophication will fill the lake or water way with sediment and plant material.

### **EPA and ADEQ Regulations**

The EPA through the 1974 Safe Drinking Water Act, has set standards for nitrogen compounds in surface and ground waters that are used in public drinking water supplies. MCLs are enforceable regulations that limit the amount of nitrate-nitrogen and nitrite to 10 mg/l and 1 mg/l, respectively. ADEQ, California EPA, and the Nevada Department of Conservation and Natural Resources have adopted these standards at the state level.

In addition, Title 18, Chapter 11, Article 4 of the Arizona Administrative Code (R18-11-405) contains a narrative for aquifer water quality standards. The narrative standard may be applied to an aquifer if nitrate "impairs" existing or reasonably foreseeable uses of water in an aquifer.

### **Detected Nitrate Concentrations**

Nitrate impacts on the Colorado River channel are largely unknown. Groundwater samples from wells adjacent to the river, however, show variable levels of nitrates up to ten times the MCL standard. Nitrate concentrations exceeding these standards have been detected in Bullhead City, Mohave Valley, Lake Havasu City, Cibola, and in the Yuma region.

Nitrate levels from wells in Lake Havasu City steadily rose from 1 mg/l in the 1970s to as high as 40 mg/l in 2001, and leveling off since then to highs in the 20mg/l range in 2005. Elevated nitrates also have been detected in wells adjacent to tributaries of the lower Colorado River, particularly along the Gila River in Yuma County, Sacramento Wash near Kingman, and in Detrital Valley in northwestern Mohave County.

Shallow groundwater systems adjacent to the River or reservoirs are directly connected, with groundwater flow directions changing as the surface water rises and falls in response to water delivery requirements. Computer modeling of the aquifer adjacent to the shoreline of Lake Havasu has shown that fluctuating groundwater flow has a direct impact on the transport of nitrates. Although slow, net flow of groundwater and nitrate migration is towards Havasu Lake. Lower River and lake conditions due to the drought will speed the migration of nitrates from groundwater to lake water.

Runoff from the Mohave and Bill Williams mountains east of Lake Havasu City after precipitation events that took place from July 2004 through February 2005, had dissolved nitrates with concentrations as high as 25 mg/l and averaging between 5-10 mg/l. There is no land development in these areas and nitrates are probably leached from subsoils containing naturally fixed concentrations of nitrate compounds.

Water samples collected and analyzed by the U. S. Geological Survey and EPA along the Colorado River over the past 30 years can be found at the following Web sites:

<http://nwis.waterdata.usgs.gov/az/nwis/qw> and  
[http://www.epa.gov/STORET/dw\\_home.html](http://www.epa.gov/STORET/dw_home.html)



## ***Current Mitigation Efforts***

Treatment options for nitrate removal from municipal and industrial wastewater include Biological Nutrient Removal (BNR), reverse osmosis, ion exchange, electrodialysis, distillation and blending. The first four methods are approved by the EPA.

Biological nutrient removal (BNR) is the process whereby nutrients are removed from wastewater in addition to the organic content (historically the focus in conventional municipal wastewater treatment). BNR for nitrogen is generally accomplished in two steps: The first step is nitrification during which non-photosynthetic bacteria, usually of the *nitrosomonas* genus, convert ammonia to nitrites. Nitrification is accomplished by the extending the aeration time in a conventional wastewater treatment system to encourage the growth of nitrogen-consuming bacteria. The second step is denitrification. Denitrification is accomplished by adding a tank that operates under anoxic conditions to encourage the growth of nitrite-converting bacteria, generally the *nitrobacter* genus, which convert nitrite to inert nitrogen gas.

Enhanced Nutrient Removal or ENR takes water that has gone through the Biological Nutrient Removal (BNR) process and further refines the effluent physically, bio-chemically or chemically to reduce nitrogen and phosphorus levels. ENR can reduce nitrogen to 3 mg/L and phosphorus 0.3 mg/L respectively, whereas BNR is generally only effective for nitrogen down to 5 mg/L.

Reverse osmosis forces water through a membrane to segregate salts such as nitrates. Ion exchange replaces nitrates in water with chlorides when water is run through an exchange resin. Individual reverse osmosis systems are commonly used in residences to remove the high dissolved solids and minerals and to improve water taste. Electrodialysis employs electricity to drive ions through a semi-permeable membrane from one solution to another and compartmentalizes the water into a low electrolyte treated water area and a high electrolyte brine area. Distillation boils water to steam and collects the steam to turn back to water, thus purifying it. Blending water simply means diluting nitrate laden water with water in which nitrate concentrations are very low.

Since these treatments are expensive on a community size basis, elimination of the source is the most cost effective alternative. Lake Havasu City and Bullhead City have instituted sewer expansion programs to reduce the number of septic tanks and drain fields along the Colorado River. There are twenty-two other entities along the River with wastewater improvement projects that have been recently completed, are currently under construction, are scheduled, or are proposed within the next 20 years that will increase cumulative treatment capacities by tens of millions of gallons per day. The cumulative project costs may be more than \$2.9 billion.

A major share (80%) of the improvement costs will occur along the reach of the River between Davis and Parker Dam. The continued rapid growth along the Colorado River, particularly in Mohave and Yuma counties in Arizona and all along the California side of the River, will challenge mitigation efforts if the developments are not well planned with respect to wastewater disposal. Ultimate disposal and quality of effluent produced from these projects will determine their effectiveness in reducing nitrate threats to the River.

Fertilizer application on agricultural fields is regulated in Arizona according to Arizona Administrative Code R18-9-402, as directed by Arizona Revised Statute §49-247, which require best management practices. These best management practices include the timing and amount of application, ground preparation, and irrigation after application. Implementation of these best management practices is intended to minimize nitrate leaching to the subsurface and periodic soil testing is required to monitor the progress of nutrient accumulation.

Some agriculture along the River has been curtailed, where fields have been laid to fallow or are in the process of being converted to wildlife habitat or are included in planned developments. Over 1300 acres of adjacent River property on the Arizona side at Cibola, south of Interstate 10 in La Paz County, will be used by the Multi-Species Conservation Program to develop riparian and upland habitat over the next 10 to 20 years. Further south on the California side of the river, an additional 3300 acres is also being considered for conversion at the Palo Verde Irrigation District. Other farmers have fallowed their land in cooperation with other state and federal programs. Developments are appearing where agriculture was once practiced in Mohave Valley and at scattered parcels in La Paz County. Less cropland means less fertilizer application, reducing the potential for nitrate introduction to the shallow groundwater and the River, however developments that include residential septic systems in their plans will continue to contribute nitrates to the shallow groundwater and the River.

Basin-wide watershed approaches through interagency coordination efforts concerning land-use are underway to study the effects of nutrients on the Colorado River system. ADEQ has conducted groundwater baseline studies with the help of the Arizona Department of Water Resources. The Multi-Species Conservation Program, administered by the Bureau of Reclamation, is an integration of federal, state, and local agencies and non-profit and private organizations to develop comprehensive, working programs for restoring or generating habitat along the lower Colorado River to protect endangered species. Part of the program's mandate is to monitor and mitigate contaminant problems that may affect restoration efforts.

## ***Recommended Solutions for Implementation and Funding***

Water quality monitoring efforts by the various agencies with respect to nutrients (in particular nitrate and phosphate) along the River system, including groundwater supplies, by federal, state and local agencies should continue. This is a cost effective measure to gauge any impacts from known problem areas and to identify any new areas of concern.

Current mitigation in the form of septic to sewer conversions in Bullhead City and Lake Havasu City should continue to eliminate their nitrate sources. Similar work needs to be done in other River communities. Conventional sewage treatment methods denitrify wastewater that otherwise would load nitrates to the subsurface and potentially to the lake. Those wastewater infrastructures already in place along the River should also be reviewed and evaluated as to their condition, efficiency and capacity. Some of these systems have been in place for many years. Upgrades and repairs should be implemented to those systems identified. Annual reports could be sent to the Colorado River Regional Sewer Coalition (CRRSCo), a diverse group of state and local agencies, Native American tribes and other organizations that have been formed to study regional sewer issues, protect and enhance water quality in the area of the lower Colorado River, and obtain federal funding for water quality improvements in the River.

To ensure that wastewater systems in new developments are built to accommodate future growth and provide adequate treatment and disposal capacities, ADEQ should:

- Coordinate with the state designated planning agencies to review and establish a process, to adjust, if necessary, the regional water quality management planning program in regard to wastewater planning. Particularly, planning for discharge locations, wastewater facility design, adequate treatment and disposal capacities, adequate treatment and disposal methods and effluent water quality should be addressed in the review.
- Make certain that treatment performance requirements for all new sewage treatment facilities (R18-9-B204) are met and require existing facilities to be upgraded to meet best available demonstrated control technology (BADCT)

ADEQ and other agencies should continue to monitor Nevada's Clean Water Coalition project to discharge up to 450 million gallons per day of effluent directly to Lake Mead immediately upstream of Hoover Dam. Further, ADEQ and other agencies should continue to monitor the U.S. Department of Energy's (DOE) action to move the 12 million tons of radioactive uranium tailings away from the Colorado River to a holding site 30 miles away at Crescent Junction, Utah. Moving the uranium tailings will reduce the threat of ammonia-nitrogen to the Colorado River. DOE plans to begin the move in the spring of 2006.

The types of fertilizers and methods of fertilizer applications on golf courses should be reviewed and recommendations developed to minimize excess nitrate available to the underlying aquifers. This may be accomplished through state and local agencies and university or private research.

Lastly, educating the public is an important aspect to minimize nutrient (nitrate) leaching into the River. Many small developments with residential septic tank systems will probably not be converted to a collection system in the near future, so imparting knowledge of wise septic maintenance will help minimize septic failures. Similarly, alerting the public to wise recreational practices concerning human waste (such as through boating safety courses) will help reduce direct impact on the River.

### **Potential Funding Sources**

The CRRSCo has been involved in assessing the nutrient conditions of the River system and has acted to seek federal funding. As a result of their lobbying efforts, Lake Havasu City was awarded in 2005 a federal earmark grant of \$1.5 million to help their sewer expansion program. This group is working to secure more federal funding for water quality improvement projects along the lower Colorado River.

Colorado River communities formed CRRSCo to educate federal government leaders about and advocate for federal resources to address water quality issues on and near the Colorado River, particularly the potential problems posed by high concentrations of residential septic tank use and potential nitrate contamination in communities along the River. In accordance with a draft Bureau of Reclamation study regarding the nitrate problem along the Colorado River, CRRSCO estimates more than \$2.4 billion is needed to construct infrastructure to alleviate the water quality problem. Taking into account current and planned activity along the River, CRRSCO estimates that there is a \$2 billion gap between available funding and the amount required to meet the wastewater infrastructure needs along the river. CRRSCO proposes a federal funding solution to these water quality issues employing a model similar to the Great Lakes Initiative or the Chesapeake Bay Program, and the Alliance strongly believes that

federal involvement and funding is needed. State and local governments simply do not have the resources to fully fund the infrastructure needed to protect the Colorado River from further degradation from nitrate concentration caused by inadequate sewage treatment.

The U. S. Department of Agriculture, through their Rural Information Center (RIC), provides extensive information and referral services to local, tribal, state and federal government officials, community organizations, rural electric and telephone cooperatives, libraries, businesses and citizens working to maintain the vitality of America's rural areas (<http://www.nal.usda.gov/ric/ruralres/funding.htm>). An example of RIC's listings is the Small Community Water Infrastructure Exchange (SCWIE), which is a network of water funding officials. Under the auspices of the Council of Infrastructure Financing Authorities (CIFA), a group of public and non-profit environmental funding and technical assistance officials have come together to create SCWIE. Within the SCWIE there is the Environmental Finance Center Network, a unique program of university-based Technical Assistance Centers that provide environmental finance outreach services to help regulated communities create innovative solutions to help manage the cost of environmental protection covering a wide array of environmental concerns, including water-related issues. Among these water-related issues are: financing issues for water quality, quantity, erosion control, preservation and infrastructure.

State level funding is available to help with infrastructure construction and maintenance. In Arizona, funding in the form of low interest loans are available through the Water Infrastructure Finance Authority (WIFA), an independent state agency authorized to finance the construction, rehabilitation and/or improvement of drinking water, wastewater, wastewater reclamation, and other water quality facilities/projects. The Greater Arizona Development Authority (GADA), an agency to provide financial assistance to political subdivisions, special districts and Indian tribes to finance or refinance infrastructure projects, is another potential funding source that is appropriate for wastewater expansion and repair projects.

In California, the Division of Financial Assistance (DFA) administers the implementation of the State Water Resources Control Board's (WRCB) financial assistance programs, which includes loan and grant funding for construction of municipal sewage and water recycling facilities, remediation for underground storage tank releases, watershed protection projects, and nonpoint source pollution control projects. DFA also administers the Office of Water Recycling and the Water and Wastewater Operator Certification Program. The WRCB also is the lead agency that administers the 319 Program of the Clean Water Act Section 319(h) nonpoint source Implementation Grant in California. In Arizona, ADEQ's Water Quality Division administers 319(h) funds. The goals of the funding program are to reduce, eliminate, or prevent water pollution resulting from polluted runoff (i.e., nonpoint sources of pollution) and to enhance water quality in impaired waters. Funds available through the 319 Program are directed towards nonpoint source implementation projects that will achieve those goals. Also within California is the Clean Water Team Citizen Monitoring Program, which provides funding resources and a list of foundation and governmental grants for projects dealing with the environment and water quality monitoring.

In Nevada, the Drinking Water State Revolving Fund is a federal program administered by the Bureau of Water Pollution Control Nevada Division of Environmental Protection, to provide free technical assistance and low-interest loans to private and public water systems in Nevada to ensure compliance with regulations of the federal Safe Drinking Water Act.

Projects, which may include wastewater construction projects if effluent is reused, are funded either as a loan out of the "account for the revolving fund" or as a non-construction project out of the "account for set-aside programs."

Other agencies that are stakeholders in water quality of the lower Colorado River and may be a source of funding are the Metropolitan Water District of Southern California and the Central Arizona Project.

## ***Action Plan for Implementation and Funding***

Following the recommendations from above, an action plan outline is offered:

- Continue existing wastewater improvement projects, with continued extensive search for outside funding sources to help pay for these projects.
- Identify areas of wastewater infrastructure improvement needs where improvement projects are not ongoing.
- Identify risk areas where nitrate contamination may exist or have a potential to develop.
- Prioritize those areas of 2) and 3) in terms of greatest needs based on contamination risk and expense of implementation.
- Search for funding to carry out the mitigating programs.
- Have ADEQ review (and revise if needed) their wastewater standards and practices to ensure that new developments have adequate sewage treatment capacity.
- Advocate for federal funding and support the efforts of CRRSCo to obtain federal funding.



## Chapter 3

### Metals

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### Pollutant Description

#### Metals as a Water Pollutant

A metal is a basic chemical element that readily forms ions and metallic bonds. Metals are one of the three principal groups of elements, along with the metalloids and nonmetals. On the periodic table, a diagonal line drawn from boron (B) to polonium (Po) separates the metals from the nonmetals. Nonmetal elements are more abundant in nature than are metallic elements, but metals in fact constitute most of the periodic table. Some well-known metals are aluminum, copper, gold, iron, lead, silver, titanium, uranium, and zinc.

All surface waters contain metals, generally appearing in colloidal, particulate, and dissolved states. Metals in surface water can result from both human activities and natural sources. Dissolved concentrations of metal ions are generally low, with most metals appearing in various oxidized forms, in combination with other elements, or adsorbed to clay, silica, or organic matter. The solubility of metals in surface waters is predominately controlled by the water chemistry (including pH), the type and concentration of other materials on which metals can adsorb (including substrate sediments and suspended sediments), the oxidation state of the minerals in which the metal is found, and other environmental factors. For example, sediment composed of fine sand and silt will generally have higher levels of adsorbed metal than will quartz, feldspar, and detrital carbonate-rich sediment. Metals have a high affinity for humic acids, organo-clays, and oxides coated with organic matter.

Water chemistry controls the rate of adsorption and desorption of metals to and from sediment. Adsorption removes free-floating metals from the water column and stores the metal in substrate. Desorption returns the metal to the water column, where recirculation and bioassimilation may take place. Metals may be desorbed from the sediment if the water experiences increases in salinity, decreases in redox potential (such as under oxygen deficient conditions), or decreases in pH.

Several metal ions such as sodium, potassium, magnesium, and calcium are essential to sustain biological life. At least six additional metals also are essential for optimal growth, development, and reproduction, i.e. manganese, iron, cobalt, copper, zinc, and molybdenum. However, where these metals are present in water in more than very small quantities, there is a danger of overdose, which can have toxic effects. In addition to the metals that are essential for life, water may also contain toxic metals like mercury, lead, cadmium, chromium, silver, selenium, aluminum, arsenic, and barium. These metals can cause chronic or acute poisoning as well as a host of other health problems in humans and wildlife. Arsenic and cadmium, for instance, can cause cancer. Mercury can cause mutations and genetic damage, while copper, lead, and mercury can cause brain and bone damage.

Metals can be transmitted to the environment through direct use of mining in ores, the burning of fossil fuels, leaching from landfills, or industrial discharges. Agriculture can also contribute to metal pollution as these elements are contained in some pesticides and as trace constituents in fertilizer. The trace elements end up in water systems through

atmospheric rain, agricultural run-off, mining wastes and domestic sewage. The hazardousness of metals can be dramatically increased as a result of bioaccumulation in the food chain.

One the key factors of metal pollution is that metals are not biologically or chemically broken down in nature. This stability also lets them be carried long distances through air and water. Most metals are hazardous for any aquatic ecosystem as well as for human health if they are present in any significant concentrations, although their ultimate polluting potential depends not only on their concentration in water but also on the form in which they are present. With the exception of mercury, the toxicity of metals is generally due to their presence in ionic form; combined forms and precipitated forms are generally less hazardous, although they can be liberated from these forms if water chemistry is unfavorable. As a result, conditions that favor the formation of metal ions (such as high salinity, low dissolved oxygen, or low pH values) generally increase the risk of metals contamination.

After reviewing available water quality information for the lower Colorado River Basin, the Alliance decided to focus on the following four metals: selenium, chromium, mercury and uranium. Each of the four metals are discussed separately.



## Pollutant Description of Selenium

Selenium is a metalloid, having characteristics of both metals and nonmetals. It occurs in nature either as a cation in compounds of sulfide, arsenide, and oxygen, or as an anion, replacing sulfur. Selenium's mobility in the subsurface is limited by the large stability fields of the selenide anion and elemental selenium and is further limited by the strong sorption of the Se(IV) oxyanion to hydrous oxides. Selenium is mobile under high oxidation and low pH conditions.

In the Colorado Grand Canyon Watershed, the following stream segments are impaired due to selenium concentrations in excess of water quality standards: the Colorado River - Parashant Canyon to Diamond Creek and in the Virgin River - Beaver Dam Wash to Big Bend Wash. In the Colorado/Lower Gila Watershed, the following stream segments are impaired: the Colorado River - Hoover Dam to Lake Mohave and in the Gila River - Coyote Wash to Fortuna Wash.



## Sources

Marine sedimentary rocks and deposits of the Late Cretaceous and Tertiary are generally seleniferous in the Western United States. Irrigation of these rocks and deposits where exposed can result in concentrations of selenium in water (Seiler, *et al.*, 1999). In the Colorado River Basin, seleniferous deposits, as sources of selenium in downstream water, have been investigated in the Grand Junction and Montrose areas of Western Colorado, near the San Juan River in Northwestern New Mexico and associated tributaries in Southwestern Colorado, and in areas along the Green River in Utah (Seiler, *et al.*, 1999). Selenium oxy-compounds are concentrated in ores together with uranium roll front deposits in Wyoming near the head waters of the Colorado River.



## Water Quality Impacts

### Human Health Effects

Trace amounts of selenium in the human diet is essential as a nutrient that is incorporated into an enzyme, glutathione peroxidase, that protects cells from oxidation. Selenium can also help in breast cancer treatment and retard the toxicity of cadmium, mercury, thallium, and silver by altering the way they react with the body. Selenium deficiency, although rare in humans, can lead to Keshan disease, which can lead to congestive heart failure. However, some studies indicate a possible correlation of high selenium diets with cancer, although not all such studies confirm this relationship. One case history of selenium poisoning from the People's Republic of China in the 1960s noted that patients' symptoms included disorders of the skin, nervous system, and teeth. That incident was related to eating food grown in high selenium soils, which were contaminated from nearby weathered coal containing high selenium concentrations.

Most selenium problems appear to be related to farm animals, but may also affect wildlife. Two major disorders with farm animals are blind staggers and alkali disease. Animals with blind staggers show acute symptoms of impaired vision, a depressed appetite, and wandering in circles after consuming plants with high selenium content.

Alkali disease develops after chronic exposure in which animals exhibit emaciation, loss of hair, deformation and shedding of hooves, loss of vitality and erosion of the joints of long bones.

Elevated concentrations of selenium was identified as the cause of mortality, congenital deformities, and reproductive failure in aquatic birds at Kesterson Reservoir on the Kesterson National Wildlife Refuge in the San Joaquin Valley in California in 1983 (Ohlendorf, *et al.*, 1988). Investigation of sources of selenium in soil in the Western United States began in the 1930s after discovery that selenium in pasturage was the cause of a fatal disease afflicting cattle and horses (Seiler, *et al.*, 1999). Selenium is also known to be detrimental to mammalian life when exposed to higher than trace levels.

A recent study conducted in the Colorado River Delta in Mexico (García-Hernández, 2005) found elevated levels of selenium in bird eggs throughout the Delta ecosystem. The mean concentration found in samples of marsh wren eggs exceeded the U.S. level of concern for selenium levels in aquatic ecosystems (generally 5 parts per billion). Based on comparisons of concentrations between wetland-inhabitant birds and birds nesting in terrestrial environments, and previous studies that have found elevated selenium levels in birds along the lower Colorado River (including the Cibola and Havasu National Wildlife Refuges) the study concluded that the likely source of this contamination is from the U.S. portion of the Colorado River as opposed to local soils in Mexico.

## **Current Mitigation Efforts**

In general, two approaches are used to manage selenium pollution. First, management of irrigation of seleniferous deposits can reduce mobilization of selenium. Secondly, avoidance of concentration of river water containing selenium to problematic levels can avoid exposing aquatic biota to harmful levels. Additionally, the ADEQ includes discharge limits for selenium in its point source discharge permits based on chronic criteria of 2 parts per billion.

Another potential approach involves flushing flows through systems affected by selenium accumulation. In the upper Colorado River this practice has proved to remove selenium concentrations in the water, sediments and biota (Hamilton, *et al.*, USGS, 2003), however this may not be feasible throughout areas affected in the Lower Colorado River.

Following the identification of selenium as a problem at Kesterson Reservoir, the United States Department of the Interior implemented, in 1985, the National Irrigation Water Quality Program to study the effects of irrigation drainage on water resources. Seiler, *et al.*, 1999 reported findings of investigations of that program. The U.S. Fish and Wildlife Service has sampled biota on the Havasu, Cibola, and Imperial National Wildlife Refuges on the lower Colorado River to determine if selenium toxicity was problematic in those areas. Combined, these efforts reveal the bioaccumulation of selenium in the aquatic food chain in these areas is evident in vegetation, invertebrates, birds and fish to levels that may be affecting eco-system productivity. Tissue sampling trends suggest continued accumulation over time may impact species diversity, and human health through regular bird or fish consumption (Rusk, 1991, King, *et al.* 1993, Andrews *et al.* 1997, Lemly *et al.* 1996, Welsh *et al.* 1994). A summarization of studies to mediate selenium food chain

impacts concludes toxic thresholds for waterborne selenium concentrations should be established at less than or equal to .003 mg/L in water (Maier et. al. 1994)

The Salinity Control Act of 1974 created the Colorado River Basin Salinity Control Program to plan and construct projects to reduce salt loading to the Colorado River (see Chapter 7 - Salinity). Improvements to irrigation infrastructure in seleniferous areas can reduce selenium loading significantly (Butler, D.L. 2001). In management of backwater areas along the lower Colorado River, such as through the Lower Colorado River Multi-Species Conservation Program, management of circulation, including funding, to avoid concentration of selenium to problematic levels is a design consideration, with monitoring to determine effectiveness.

### ***Recommended Solutions for Implementation and Funding***

Support continued funding for the Colorado River Basin Salinity Control Program to reduce salt loading in areas with sources associated with seleniferous deposits.

Encourage the Colorado River Basin Salinity Control Forum to address the constituents of salinity in areas where there are water quality impacts due to those individual constituents. Local officials should avoid development projects or programs that will result in further concentrations of selenium in areas that will affect local drinking water sources or will be frequented by birds and other wildlife (such as evaporation ponds, isolated backwaters without adequate circulation, or concentrated agricultural drains).

Develop coordinated monitoring activities, potentially through the Lower Colorado River Multiple Species Conservation Program (MSCP) to determine trends of selenium concentrations in both the water column and target species throughout the lower Colorado River.

Monitor fish tissue for selenium concentrations of species most commonly consumed by humans on a revolving three year basis from Lake Havasu to the international border.

### ***Action Plan for Implementation and Funding***

Support continued funding for the Colorado River Basin Salinity Control Program. (see also Chapter 7 - Salinity) Engage the services of the Lower Colorado River Resource Conservation and Development Council (RC&D) to seek financial support of selenium monitoring efforts.

## Pollutant Description of Chromium

Chromium is a multi-valent metal found naturally in all igneous rocks, but is more concentrated in ultramafic igneous rocks, sometimes as an ore of iron or lead. Chromium is also present in soils, mobilizing under aerobic conditions. The most common forms of chromium in groundwater are the relatively insoluble trivalent form, Cr(III), which occurs in anaerobic conditions and is usually precipitated as chromium hydroxide ( $\text{Cr}(\text{OH})_3$ ), and the soluble hexavalent form, Cr(VI), which occurs as either the chromate ( $\text{CrO}_4^{2-}$ ) or dichromate ( $\text{Cr}_2\text{O}_7^{2-}$ ) ion. Both forms usually occur naturally in low concentrations, but may be higher near geologic sources or through introduction by human activities. Of the two forms, only Cr(VI) is considered dangerous to human and environmental health.

The transport of chromium in groundwater is highly dependent on the interplay of the pH, the organic matter, mineral, and clay content, and the oxidation conditions. Chromium adsorption to organic matter, clay mineral, ferrous iron, or sulfide mineral surfaces and subsequent reduction to Cr(III), occurs under anaerobic and lower pH conditions. As groundwater becomes more oxidized and alkaline, chromium must compete for adsorption with more common ions, keeping it in the mobile Cr (VI) form. The presence of manganese oxides and hydroxides, which may be common in groundwater along the Colorado River, also helps to stabilize Cr(VI), giving the opportunity for long transport paths.

## Sources

Hexavalent chromium, in the form of chromate ( $\text{CrO}_4^{2-}$ ) and dichromate ( $\text{Cr}_2\text{O}_7^{2-}$ ) salts, is used in a wide variety of industrial activities and products such as its use as a pigment in paints, printing inks, and plastics, and as a constituent in metal alloys, hard chrome plating, corrosion inhibitors, refractory bricks, photographic film, wood preserving, and leather tanning. Industrial applications such as spraying, plating, and welding release chromium dust to the atmosphere.

Disposal of fly-ash from coal combustion is the largest release to soils by human activity. Illegal dumping of chromate solutions and sewage sludge disposal to the land surface are other significant sources of chromium to soils. Wood preserving solutions containing chromated copper arsenates carry an added threat of arsenic contamination if such solutions were released into the environment.

## Water Quality Impacts

### Health Concerns

Chromium enters the body by ingestion or by inhalation, although direct contact on the body can lead to systemic poisoning, dermatological ulcer generation, and if eyes are exposed, permanent eye damage may result. Chromium inhalation can cause lung cancer and respiratory tract ailments that could lead to nasal septum piercing and asthma. Air borne chromium dust has the double threat for direct inhalation and settling into a drinking water body to be later consumed. Chromium has even been known to accumulate onto cigarettes, which when smoked, is inhaled by the smoker. Long term ingestion of chromium in water or foods can lead to kidney and liver dysfunctions, nerve tissue damage, and internal hemorrhaging.

## **Environmental Concerns**

The environmental effects to the biological community include toxicity to plants and aquatic life, yet chromium does not appear to bioconcentrate in food chains. Chromium is more toxic in soft water than in hard water. The acute toxic effects may be observed within two to four days of contact include the death of animals, birds, or fish, and death or low growth rate in plants. Chronic toxic effects may include shortened lifespan, reproductive problems, lower fertility, and changes in appearance or behavior. Soils containing high concentrations of chromium have become sterile.

## **EPA and State Regulations**

The U. S. EPA's and ADEQ's maximum concentration level (MCL) in drinking water is 100 ppb for chromium. Arizona's surface water quality standards for hexavalent chromium to protect the domestic water source use is 21 ppb; while the chronic aquatic life standard is 1 ppb.

## **Detected Chromium Concentrations**

Total chromium concentrations in the Colorado River and its associated reservoirs are and have been below the MCL standards for drinking water; however, there are two locations where hexavalent chromium is impacting groundwater adjacent to or near the river. These occur at the highly publicized Pacific Gas & Electric (PG&E) Compressor Station site on the California side of the river at Topock (I-40 river crossing) and at the former McCulloch manufacturing plant in Lake Havasu City (LHC), Arizona. The plume of hexavalent chromium bearing groundwater contains as much as 700 ppb and has traveled several hundred feet from its source to within 60 feet of the Colorado River. Investigations and mitigation efforts are underway to define the extent of the Cr(VI) presence under order of the California Department of Toxic Substances Control. ADEQ is monitoring these efforts.

The second plume of chromium 6+ in LHC is being monitored by the current land owner and a monitoring well drilling program has identified most of its extent. Manufacturing operations at the old McCulloch chainsaw and outboard motor plant used chromium 6+ for plating metals. Hexavalent chromium occurs in the vadose zone above the water table where the chromium solutions were released; however a 1,200 feet long and 275 feet wide plume extends towards the River below the water table. The known downstream edge of the plume is about 3,800 feet from the River. Total chromium concentrations measured thus far range up to 240,000 ppb.

## ***Current Mitigation Efforts***

Both known hexavalent chromium sites in the lower Colorado River area are being monitored, and mitigation efforts are underway at the Topock location. Groundwater extraction wells adjacent to the River channel at Topock began pumping in early 2004 to help remove the impacted water and to create a reverse groundwater flow field that effectively deflects the groundwater from entering the river. Injection wells also have been drilled to re-inject treated water back into the aquifer. A sediment coring project in the River channel up and down stream of the facility will be conducted to determine the extent of contamination underneath the River channel. Officials from the California Environmental Protection Agency, the Arizona Department of Environmental Quality, and

the U.S. EPA have been following the mitigation work. ADEQ has initiated a groundwater study on the Arizona side of the River to help in determining whether chromium contaminated groundwater has reached Arizona.

Installation of additional monitoring wells and continued monitoring near the McCulloch site in Lake Havasu City is expected to better define the extent of that plume. Calcium polysulfide has been injected into a test well to convert hexavalent chromium to trivalent chromium.



## ***Recommended Solutions for Implementation & Funding***

Continued monitoring and mitigation efforts should continue at the two known sites to remediate the impact in the groundwater systems adjacent to the Colorado River. More work is needed at the Lake Havasu City site to determine the full extent of the hexavalent chromium contamination and what methodologies are most prudent to remediate the situation.

Hexavalent chromium analyses should be included in all River water sampling programs, particularly downstream from the PG&E Topock site. A GIS-based review of other industry activities, past and present, along the Colorado River should be instituted to determine any other potential sites that threaten the River system. If any are identified, environmental Phase I investigations are warranted, and if necessary, Phase II on-site investigations to determine the extent and degree of contamination. The next step in the process is Phase III remediation to clean the site(s).

### **Potential Funding Sources**

In most cases, the land owner of the toxic contamination site pays for the investigations and remediations, which has been the case for the two known chromium VI contaminated sites. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or Superfund program administered by the U. S. EPA has helped to pay for hexavalent chromium remediation at sites in the past.

The Arizona Water Quality Assurance Revolving Fund (WQARF) also might be a potential source of clean-up funds although WQARF has not been fully funded by the Arizona legislature in recent years.



## ***Action Plan for Implementation & Funding***

- ADEQ should continue to monitor clean-up of the two known sites on the river.
- Investigate other potential sites along the River.
- Prioritize and address any potentially additional threatened sites.

## Pollutant Description of Mercury

Mercury is a naturally occurring element found most often in the form of mercury sulfide (HgS) in volcanic rocks such as cinnabar, or in liquid form as "quick-silver". Mercury also occurs as an accessory element in many common rock types such as granite or shale and is found in elevated amounts in some coal deposits. Because mercury can undergo two types of chemical reactions (oxidation-reduction and methylation-demethylation), in the environment, mercury may be found as elemental mercury (Hg 0), inorganic mercury (Hg + 1 or Hg + 2), or organic mercury [monomethyl mercury:  $\text{HgCH}_3$  + or dimethyl mercury:  $\text{Hg}(\text{CH}_3)_2$ ].

## Sources

Naturally occurring mercury can be mobilized in the environment through excavation, hard rock mining/ore processing, or volcanic activity. Because of its amalgamating capacity, mercury was used extensively during the gold rush, particularly in placer mining, but also in lode operations prior to the use of cyanide in the 1920s. Arizona and the surrounding states share a history of extensive mining, including both lode and placer gold mining. Figure 3-1 shows existing mining activity in Arizona; note the gold mine sites within the Colorado River drainage. Aerial sources of mercury may include waste incineration, coal fired power plants, cement and lime kilns, smelters, pulp and paper mills, chlor-alkali factories, and forest fires. Figure 3-2 shows both potential regional aerial sources and mercury-contaminated lakes in Arizona as of 2003.

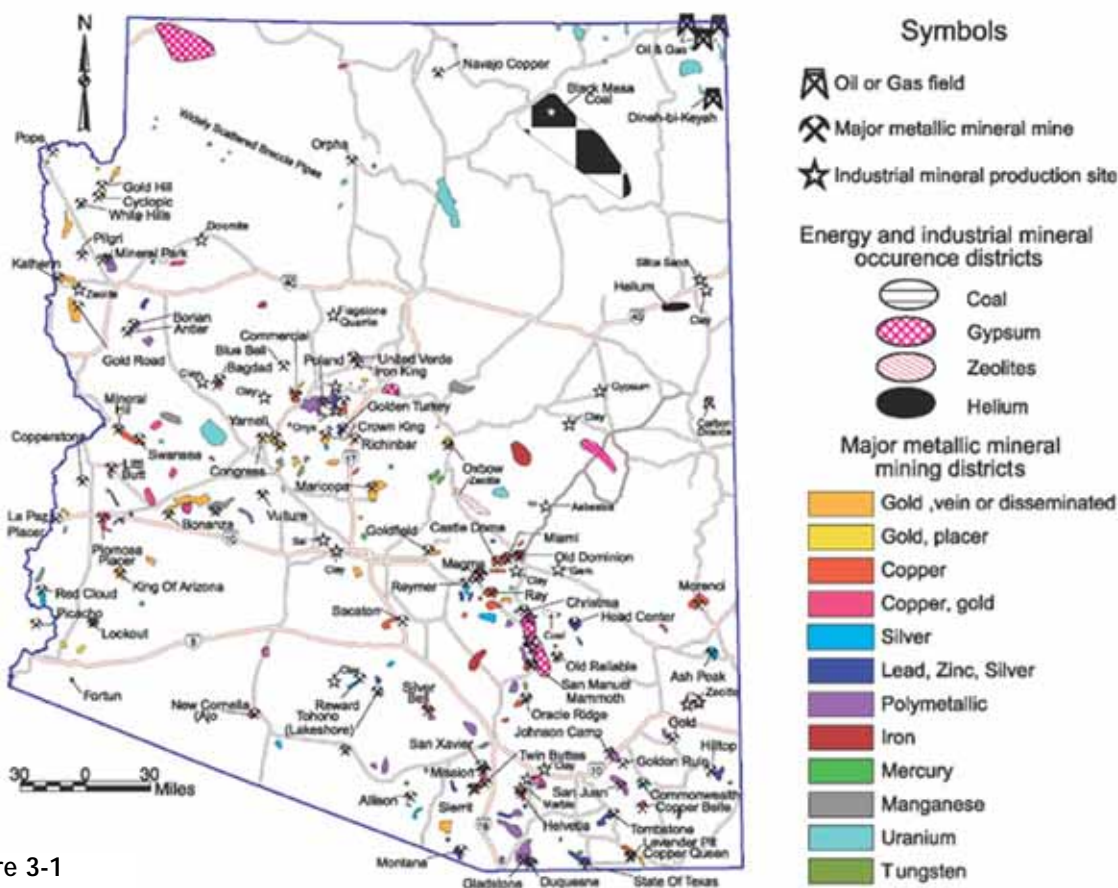


Figure 3-1

# Potential Aerial and Geologic Sources of Mercury Contamination to Arizona Lakes

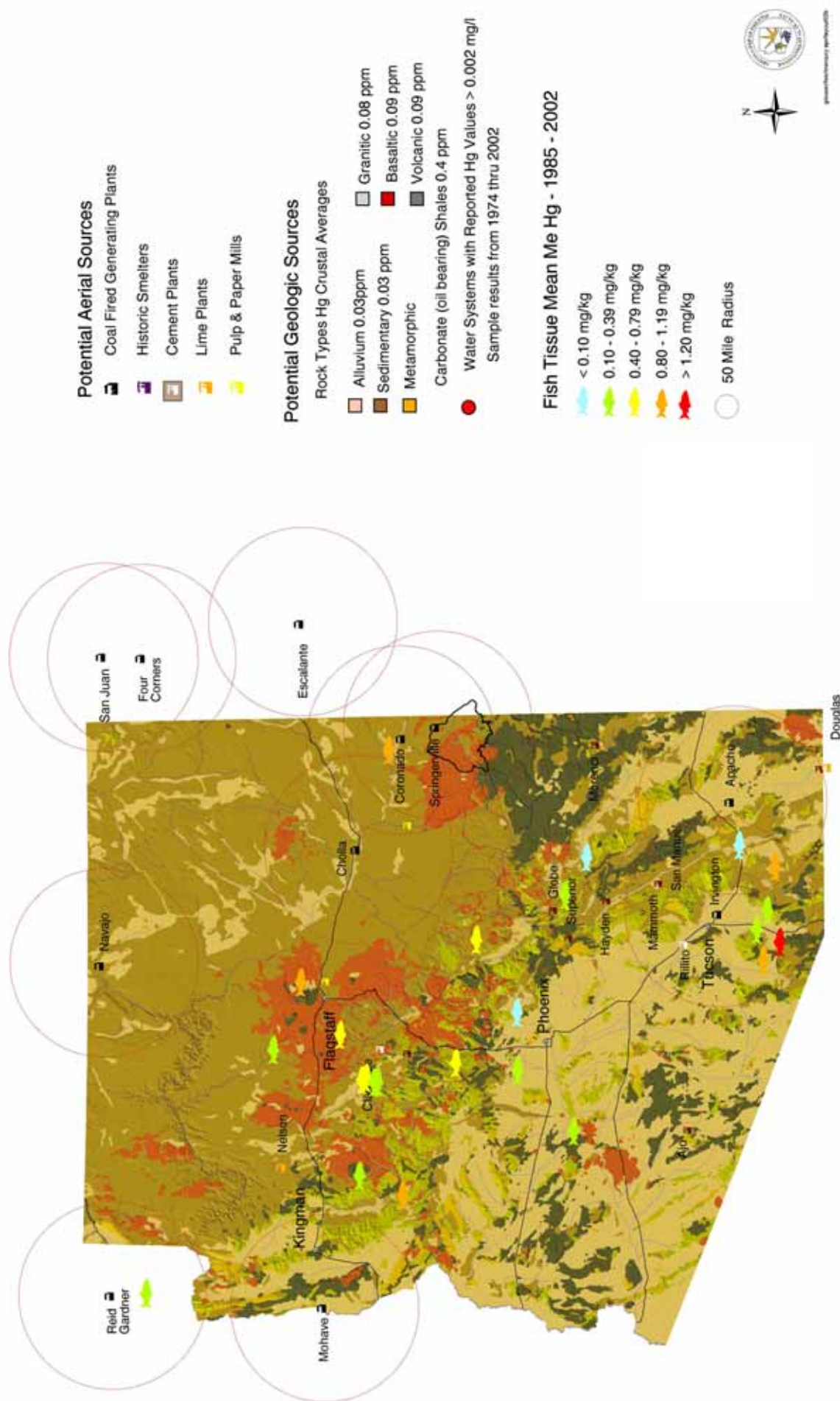


Figure 3-2

## **Uses of Mercury**

Mercury has been extracted and used in manufacturing and industry for centuries. Among the various uses are: pigments, light bulbs, dental fillings, batteries, thermometers, electrical equipment (switches), chemical processing (e.g., chlorine and caustic soda), pesticides, and such things as the manufacture of felt hats or pharmaceuticals. Anthropogenic sources of mercury have become a global phenomenon and therefore its environmental fate and transport have become a global concern because of potential toxicity and its tendency to bio-accumulate.

## **Human Health and Environmental Concerns**

Mercury can be toxic when inhaled, eaten, or placed on the skin. Depending on the chemical form and the dose received, mercury can be toxic to both humans and wildlife. In people, toxic doses of mercury can cause developmental defects in the fetus, as well as kidney and nervous system damage. High level exposures can be lethal, such as occurred in Minamata, Japan (1953-1960) from consumption of contaminated fish, or in Iraq (1971-1972) from ingestion of fungicide-tainted bread. Mercury has been shown to bioconcentrate up aquatic and marine food chains increasing the risks to top predators, including humans.

Increasingly, Arizona lakes and reservoirs are being listed as impaired due to high levels of methyl-mercury in fish tissue. One pertinent example is Alamo Lake in the Bill Williams watershed, which drains to the Colorado River system at lower Lake Havasu just above Parker Dam and the Central Arizona Project (CAP) intake structure.. The Clean Water Act requires that a Total Maximum Daily Load (TMDL) analysis be conducted on impaired surface waters to achieve standards compliance. TMDL sampling and analysis for Alamo Lake (ADEQ, (2004-2005) has revealed specific areas within the watershed that show elevated sediment and suspended sediment mercury that correlates with historic gold mining and a massive sulfide deposit. The contribution of aerial deposition (both wet and dry) has been estimated to be less than 20% of the total mercury load reaching Alamo Lake. For a more accurate analysis of mercury deposition in general, ADEQ has committed funds to support the first Mercury Deposition Network (MDN) site in Arizona.

## **Detected Mercury Concentrations**

As mentioned, mercury has been detected in water and sediment in the Alamo Lake watershed using ultra-clean, low-level analytical methods. Mercury is present in the Alamo Lake discharge to the Bill Williams River downstream (tributary to the Colorado River near Parker), and there are also abandoned mines below Alamo Lake (e.g., Mineral Hill Mine) that drain to the Bill Williams National Wildlife Refuge. Mercury may also be entering the Colorado River between Lake Mead and Lake Havasu from areas such as Gold Road or Gold Hill. The threat of mercury contamination from other potential sources within the Colorado River drainage has not been determined with any certainty.

In the Bill Williams Watershed, the following segments are impaired due to mercury in excess of water quality criteria: in Burro Creek from Boulder Creek to Black Canyon and in Boulder Creek from an unnamed tributary to Butte Creek.

Waters also may be impaired due to mercury in fish tissue in excess of the standard. In the Bill Williams Watershed, Alamo and Coors lakes are impaired due to mercury in fish tissue. In the Little Colorado River Watershed, Upper Lake Mary, Lower Lake Mary, Soldiers Lake, and Soldiers Annex Lake are impaired due to mercury in fish tissue.

U.S. Fish and Wildlife studies published in 1993 and 1997 cite mercury detections in largemouth bass collected along the Colorado River corridor. The highest level of mercury detected was found in a fish from the Bill Williams National Wildlife Refuge (0.13 ug/g wet weight) but still well below fish levels found by AGFD/ADEQ in Alamo Lake (0.3 – 1.1 ug/g wet weight). Higher trophic-level birds such as eagles, osprey, or grebes that eat fish are particularly at risk.

Clark's grebes also showed the highest mercury level in an individual collected at the confluence of the Bill Williams and Colorado River (3.65 ug/g in liver; 5.38 ug/g in kidney, as compared to the "extremely hazardous" concentration of 20 ug/g suggested in the literature).

### **EPA and State Regulations**

Mercury is regulated through the Clean Air Act and the Resource Conservation and Recovery Act, as well as the Safe Drinking Water Act and the Clean Water Act. It is one of approximately 120 priority pollutants. Because mercury is emitted as a byproduct of coal and oil combustion, emissions from power plants constitute about 40 percent of total U.S. mercury emissions annually.

The Safe Drinking Water Act establishes Maximum Contaminant Levels (MCLs) for mercury at 2.0 ppb (total mercury). Arizona Surface Water Standards cite this standard under Domestic Water Source, along with more stringent standards for aquatic and wildlife use (0.01 ug/L dissolved mercury for chronic exposure; 2.4 ug/L dissolved mercury for acute exposure).

### ***Current Mitigation Efforts***

Within the Bill Williams watershed, efforts are being mobilized to contain and cap the three tailings piles at Hillside Mine (Boulder Creek). Sampling for the Alamo Lake TMDL identified additional areas where further investigation is needed (Copper Basin/Skull Valley Wash; middle Santa Maria River, and upper Big Sandy River) to focus mining source attribution.

### ***Recommended Solutions for Implementation & Funding***

- Conduct a detailed mine survey, focusing on gold mining operations.
- Conduct further fish and wildlife testing along the Colorado River.
- Conduct clean mercury sampling with low-level detection in the main stem of the Colorado River and backwaters (if fish and wildlife levels warrant).
- Support additional air deposition monitoring stations in Arizona.

#### **Potential Funding Sources**

- Clean Water Act Nonpoint Source/TMDL Implementation grants (§ 104(b)(3) & §319).
- Federal agencies including: USFWS; BLM, USFS.
- State agencies: AGFD, ASLD, Mines & Minerals.

### ***Action Plan for Implementation & Funding***

- Interagency coordination to develop and implement further investigation.
- Identify localized mercury sources and prioritize remedial projects.

## Pollutant Description of Uranium

Uranium is a natural and commonly occurring radioactive element. Rocks, soil, surface and underground water, air, and plants and animals all contain varying amounts of uranium. It is a reactive metal, so it is not found as free uranium in the environment. Typical concentrations in most materials are a few parts per million (ppm). Some rocks and soils may also contain greater amounts of uranium.

Natural uranium is a mixture of three types (or isotopes) of uranium: U-234, U-235, and U-238. U-234 is by far the most radioactive of the three isotopes and has the shortest half-life (the time it takes for half of the isotope to give off its radiation and change into a different element). Uranium decays through a series of different radioactive materials, eventually transforming into lead. The half-lives of uranium isotopes are very long (244 thousand years for  $^{234}\text{U}$ , 710 million years for  $^{235}\text{U}$ , and 4 1/2 billion years for  $^{238}\text{U}$ ). Because U-235 and U-238 have such long half-lives, the uranium found in the earth today is the same metal that was present when the planet was formed.

Uranium is usually found only in very small amounts in nature, but where the concentrations of uranium in rock are high enough, the rock is considered a uranium ore and may be mined. After the uranium is extracted from ore, it is converted into uranium dioxide or other chemical forms. The residues remaining after uranium has been extracted are called mill tailings. Mill tailings normally contain a small amount of uranium, as well as other radioactive waste products such as radium and thorium. Uranium in mill tailings can combine with other chemicals in the environment to form various uranium compounds. Each of these uranium compounds dissolves to a different extent in water, ranging from not soluble to very soluble. The solubility of these compounds determine how easily the compound can move through the environment, as well as how toxic they are.

## Sources

Uranium is found at low levels in virtually all rock, soil, and water. Significant concentrations of uranium occur in some substances such as phosphate rock deposits, granitic rocks (a source of radon gas), and minerals such as uraninite and carnotite in uranium-rich ores. Sulfide and selenium deposits are associated with uranium ore bodies.

Anthropogenic sources include uranium ore body mill tailings from which precipitation runoff leaches the uranium compounds and the settling of uranium dust out of the air (in addition to soil dusts, coal-fired power plants normally emit some level of uranium dust). The levels of uranium in water in different parts of the United States are extremely low in most cases, and water containing normal amounts of uranium is usually safe to drink. Plants can absorb uranium from the soil onto their roots without absorbing it into the body of the plant. Therefore, root vegetables like potatoes and radishes that are grown in uranium-contaminated soil may contain more uranium than if the soil contained levels of uranium that were natural for the area.

## **Uses of Uranium**

Uranium ore can be mined by underground, open-cut methods, or subsurface solution-leaching, depending on its depth and type of geologic environment. After mining, the ore is crushed and ground up. Then it is treated with acid to dissolve the uranium, which is then recovered from solution. Uranium may also be mined by in situ leaching, where it is dissolved from the orebody in situ and pumped to the surface. The end product of the mining and milling stages, is uranium oxide concentrate ( $\text{U}_3\text{O}_8$ ), the conventional form in which uranium is sold. These mining and refining processes produce wastes such as mill tailings which may be introduced back into the environment by wind and water if they are not properly controlled.

When refined, uranium is a silvery white, weakly radioactive metal. Uranium in ores can be extracted and chemically converted into uranium dioxide or other chemical forms usable in industry. Depleted uranium is used by the military as shielding to protect Army tanks and also in parts of bullets and missiles. The military also uses enriched uranium to power nuclear propelled Navy ships and submarines, and in nuclear weapons.

The main civilian use of uranium is in nuclear power plants, helicopters and airplanes. Very small amounts are used to make some ceramic ornament glazes (added for color), light bulbs, photographic chemicals, and household products. Phosphate fertilizers often contain high amounts of natural uranium, because the mineral material from which they are made is typically high in uranium.

## **Human Health & Environmental Concerns**

The release of radiation during the decay process raises health concerns. However, unlike other kinds of radiation, the alpha radiation ordinarily given off by uranium cannot pass through solid objects, such as paper or human skin. To be exposed to radiation from uranium, humans have to eat, drink, or breathe it, although some uranium transformation products produce more dangerous levels and types of radiation.

Because of the relatively weak radioactive character of uranium, uranium's chemical effects are likely more dangerous than the radiation it emits, although some of the transformation compounds associated with uranium (such as radium) are potentially hazardous. Some studies have suggested a correlation between kidney disease and exposure to large doses of uranium in both people and animals, as well as correlations to a type of bone cancer known as sarcoma. Since uranium tends to concentrate in specific locations in the body, risk of cancer of the bone, liver cancer, and blood diseases (such as leukemia) are also increased. Inhaled uranium increases the risk of lung cancer. Very high doses of uranium have caused reproductive problems (reduced sperm counts) in some experiments with laboratory animals. Very high doses of uranium in drinking water can also affect the development of a fetus in studies of laboratory animals.

Waste generated from uranium mining operations and rainwater runoff, if not properly managed, can contaminate groundwater and surface water resources with heavy metals and traces of radioactive uranium. The toxicity of uranium to fish varies with water quality particularly total hardness and alkalinity. It accumulates in soils and sediment and enters the food chain by adsorption on surfaces of plants and animals and by ingestion of sediments and contaminated food. Therefore, bottom-feeding fish have a higher risk due to accumulation than higher order predator fish.

## **EPA and State Regulations**

EPA standards under the Clean Air Act limit uranium in the air. The maximum dose to an individual from uranium in the air is 10 millirems. Uranium in drinking water is covered under the Safe Drinking Water Act. This law establishes Maximum Contaminant Levels, or MCLs, for radionuclides and other contaminants in drinking water. The current standards are: combined radium 226/228 of 5 pCi/L; a gross alpha standard for all alphas of 15 pCi/L, not including radon and uranium; a combined standard of 4 mrem/year for beta emitters. The MCL for uranium is 30 ppb.

In 1978, Congress passed the Uranium Mill Tailings Radiation Control Act (UMTRCA) in response to public concerns regarding potential health hazards of long-term exposure to radiation from uranium mill tailings. UMTRCA requires DOE to establish a remedial action program and authorizes DOE to stabilize, dispose of and control uranium mill tailings and other contaminated material at uranium-ore processing sites and associated properties. EPA has issued special regulations for cleaning up uranium mill tailing sites in Title 40 Code of Federal Regulations 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings. The cleanup of contaminated sites to be released for public use, must meet EPA's risk-based criteria for soil and ground water. EPA's site cleanup standards limit a person's increased chance of developing cancer to between 1 in 10,000 to 1 in 1,000,000 from residual uranium on the ground.

## **Detected Uranium Concentrations**

ADEQ has reviewed over 20 years of available water quality data for the Colorado River from the Utah border to the border with Mexico and found no exceedances of the surface water quality standard for uranium of 35 µg/l. However, there are a number of active or abandoned uranium millsites located along the Colorado River and its tributaries; of these, one Utah site, near Moab, in particular represents a significant potential source of uranium contamination in the Basin.

Among its provisions, UMTRCA charged DOE with reclaiming nine abandoned uranium millsites located within the floodplain of the Colorado River or its tributaries. Typically the tailings wastes at these sites were increasing radon levels in the local air and had seeped into the groundwater, where plumes of contamination threatened to enter the rivers. In each case, DOE decided to move the tailings to new disposal cells away from surface and groundwater, investing nearly \$2 billion in the program by the late 1990s. Only ongoing groundwater treatment remains to be done in this effort.

The 1978 Act also provided for the Nuclear Regulatory Commission (NRC) to oversee eventual owner-funded reclamation of uranium mills still actively in business. This included the Atlas Mill along the Colorado River near Moab, Utah, formerly Uranium Reduction Company (URC) ore processing facility. This mill was the first commercial uranium mill in the U.S. and the largest ever built beside a river. The mill ceased operations in 1984 but over its many years of operation, approximately 10.5 million tons of uranium mill tailings have accumulated on site as a nearly 100 foot tall, 130-acre tailings pile. While the milling process removed approximately 95% of the uranium, the tailings contain several naturally occurring radioactive elements, including uranium, thorium, radium, polonium and radon as well as other pollutants.

The Atlas tailings pile averages 94 feet above the Colorado River floodplain and is about 750 feet from the Colorado River. The pile was constructed in a series of terraces and also contains

debris from dismantling the mill buildings and other structures. Radiation surveys indicate the tailings contain radioactive contaminants at concentrations above the EPA standards. Besides tailings and contaminated soils, other areas with environmental issues include unlined ponds used during ore-processing activities, disposal trenches, and other locations used for waste management during facility operation.

Initially, Atlas proposed, and the NRC approved, a plan to simply cover the unlined wastes in the River's floodplain. However, this proposal generated objections from the local government and a full EIS was prepared. During the course of preparing the EIS, it was discovered that leakage from the tailings pile and other hotspots on the mill property had contaminated the groundwater and the Colorado River into which it discharges. Studies showed that tailings seepage into groundwater had averaged 57,000 gallons/day during the 40-year life of the mill and that approximately 110,000 gallons of this tainted groundwater were reaching the River daily. The underground plume is more than 5,000 feet wide and extends more than 40 feet below the surface. Contaminants present in high amounts include uranium, molybdenum, selenium, ammonia, nitrates and sulfates among many others, with ammonia levels high enough to be immediately lethal to fish.

Faced with unexpected water treatment costs, Atlas Corporation declared bankruptcy in 1997, leaving behind a reclamation bond of approximately \$5 million. A coalition of environmentalists, politicians and water districts with more than 25 million consumers of this water succeeded in getting legislation passed in 1999 transferring responsibility for the site to the DOE.

DOE prepared another EIS and found that the tailings pile is built in the center of an alluvial fan, vulnerable to possible failure during a large flood. The Arizona Department of Environmental Quality expressed its serious concerns about the impact of the tailings pile on water quality in the Colorado River to urge DOE to move the waste by rail, thirty miles north to a new disposal cell near Crescent Junction, Utah. Actual tailings removal is scheduled to begin in 2007 and continue until 2017.

## ***Current Mitigation Efforts***

In addition to moving the tailings, DOE will also implement active ground water remediation at the Moab milling site. Groundwater in the shallow alluvium at the site was contaminated by the milling operations. As ADEQ expressed in its comments to DOE, the Colorado River adjacent to the site has been negatively affected by site-related contamination, mostly because of groundwater discharge. The primary contaminant of concern in both the ground water and surface water is ammonia, which is highly toxic to aquatic life. Other contaminants of concern are manganese, copper, sulfate, and uranium. The reclamation plan calls for a pump and treat system that would extract groundwater and treat it to standards. It is anticipated to take between 75-80 years to remediate the groundwater at an estimated cost of nearly \$500 million. Removal of the tailings produces a secondary benefit of reducing seepage of ammonia-nitrogen from the tailings, either subsurface or through surface discharge into the Colorado River.



**Figure 3-3.** Aerial view of the Moab site in 2001 identifying the locations of the tailings pile, Moab Wash, Colorado River, upstream background sampling location and the Matheson Wetlands Preserve.

### ***Recommended Solutions for Implementation and Funding***

ADEQ should continue to monitor the U.S. Department of Energy's (DOE) action to:

- Move the 12 million tons of radioactive uranium tailings away from the Colorado River to a permanent disposal location 30 miles away at Crescent Junction, Utah
- Conduct active groundwater remediation on-site. Until the project becomes a permanent DOE budget line item, it will be necessary to assure each year that sufficient federal appropriations are made to keep the work on schedule.

### ***Action Plan for Implementation and Funding***

ADEQ should continue to monitor the U.S. Department of Energy's (DOE) removal of the uranium tailings pile and groundwater remediation at the former Atlas Minerals facility near Moab, Utah. Moving the uranium tailings will reduce the threat of uranium, ammonia and other pollutants to the Colorado River.



## Chapter 4

### Endocrine Disrupting Compounds

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### Pollutant Description

Endocrine disrupting compounds (EDCs) are an emerging group of potential water contaminants about which relatively little is known. EDC is a descriptive phrase for a broad group of natural and synthetic organic compounds that block or mimic normal receptor-activating hormones in the human endocrine system. They also may act as triggers activating the hormone system at undesired times and at undesired levels. The endocrine system plays an important role in maintaining the body's internal steady state (e.g. nutrition, metabolism, excretion, water and salt balance), regulation of growth, reaction to outside stimuli, and production and storage of energy. Normally, hormones produced from the endocrine glands carry messages to various parts of the body in response to nerve cell or gland stimuli and they attach themselves to a receptor cell. The receptor cell carries out the hormone's instructions and can either turn on genes to create new proteins for long-term effects (e.g. growth or sexual maturity) or can alter the activity of existing proteins to respond to the stimuli (e.g. faster heart beat, vary blood sugar levels).

Endocrine disrupting compounds can mimic the body's hormones and slip into receptor sites, but they do not carry the intended messages, effectively blocking the normal endocrine process, or altering it in a negative way. Some chemicals called environmental estrogens, can act like estrogen or androgen, altering sexual maturity in some fashion. Such changes include low sperm counts, early puberty in females, possible breast cancer increased incidents, and higher rates in testicular cancer. Those chemicals that block or alter hormonal binding to the receptor cells are called anti-estrogens. Still other chemicals can alter production and breakdown of natural hormones or modify the development and function of receptor cells. Exposure to EDCs may not result in a direct effect on the living organism, but may significantly alter the reproductive process with devastating results: the disruption of community structure and the ecosystem process.

Pharmaceuticals (prescription or not) are a category of possible EDCs. They affect the body because they are designed to specifically influence human receptors and many are lipophilic, which readily dissolve in fatty tissue, but not in water. The body uses the necessary part of the drug, and the rest is eliminated, eventually ending up in the environment. Most research has gone into two major classes of pharmaceutical effects: the promotion of pathogen resistance to antibiotics and the disruption of endocrine systems by natural and synthetic sex steroids. Other classes of concern to the EPA are anti-depressant selective serotonin reuptake inhibitors (SSRIs), calcium-channel blockers, efflux-pump inhibitors, antiepileptics, and genotoxic chemotherapeutic agents.

EDCs also may be a threat to the natural environment. Most EDCs, can accumulate within organisms and may negatively impact aquatic ecosystems by affecting various physiological processes in organisms. Preliminary studies indicate increased cancer rates, reproductive abnormalities, impaired reproduction, and development of bacteria with antibiotic resistance. Concerning the last issue, bacteria in the environment is exposed to antibiotic-bearing effluent and adapts to these chemicals, making them harder to destroy with antibiotics if they infect a person.

## Sources

EDCs have a wide variety of origins both natural and synthetic with the pharmaceutical and chemical industries leading the way with synthetic production. Some EDCs are naturally occurring, such as phytoestrogens produced by plants. The pharmaceutical industry intentionally creates EDCs (i.e. health related drugs such as antibiotics, codeine, and acetaminophen) to correct the body's health problems, effectively restoring the body's normal behavior. The advent and increased use of contraceptives has also contributed to the amount of pharmaceutical EDCs released into the environment. In addition, the chemical industry unintentionally produces EDCs as byproducts of manufacturing or in agricultural applications. EDCs such as nonylphenol, alkylphenol ethoxylates (APEs), and phthalates are often found in common household items, such as detergents, cosmetics, personal care products, household cleaners, and even in plastic food containers. Several pesticides contain known or suspected endocrine disrupting compounds that enter our bodies through residues on food, which may be eliminated from the body and into the aquatic environment. Food and tobacco products also contain chemicals such as caffeine and nicotine derivatives that persist in the aquatic environment. Heavy metals like lead, mercury and cadmium are also byproducts of manufacturing and enter waterways via disposal from these facilities.

Pharmaceuticals in waste water effluent are a growing source of concern as more and more drugs are produced and consumed, and as the population increases along the Colorado River. The body utilizes the drugs, but eventually excretes unused portions, which make their way into septic or sewer systems, all of which eventually lead to groundwater infiltration that migrates to the River or is directly discharged to the River. Household cleaners and personal care products also end up either in groundwater or sewage treatment plants. Las Vegas is currently discharging effluent that eventually drains into Lake Mead, and along with Henderson and Clark County, Nevada has proposed to directly discharge up to 450 million gallons per day of treated effluent into the deeper parts of Lake Mead. There also are locations on the River where effluent is disposed through percolation or natural infiltration from effluent use. Table 4-1 gives a partial list of EDC sources and the type of EDC associated with the source.

**Table 4-1: Types of and potential sources of EDCs**

EDC Sources	EDC Category	EDCs
Landfill	Polychlorinated compounds	Polychlorinated dioxins and biphenyls
Agricultural runoff	Organochlorine pesticides	DDT, dieldrin, lindane
Industrial effluent	Alkylphenols and Phthalates	Nonylphenol, dibutyl phthalate, butylbenzyl phthalate
Municipal Effluent	Natural hormones, synthetic steroids, pharmaceuticals	Estradiol, estrone, testosterone, ethynyl estradiol
Atmospheric/ Combustion Emissions	Androgenic	Oxygenated organic species



## ***Water Quality Impacts***

Much research is being conducted to understand the role of EDCs in water quality issues. This group of chemicals was not considered a problem in the 1970's through much of the 1990's as their concentration levels in surface and ground water were and still are in most cases below detection limits of analytical procedures. New technology has pushed the detection limit to the fraction of a microgram per liter (parts per trillion) level. EDCs, including pharmaceutical and personal care products, are introduced into surface waters via treated wastewater inputs, confined animal facilities, runoff of terrestrial pesticide formulations, household cleaning products, industrial processes, and direct application with tank-mixed aquatic pesticides. The US Environmental Protection Agency (EPA) has put maximum concentration level limits (MCLs) concerning drinking water quality on several EDCs; however, most chemicals within the EDC family have not been studied enough to ascertain their health effects and currently are not regulated.

### **EDC's Measured in Colorado River Water**

Generic sampling of river and lake water related to EDCs along the Colorado River (particularly in Lake Havasu) do not indicate any immediate threats from EDCs, yet a 2000-2001 U.S. Geological Survey study of Lake Mead and Las Vegas Wash focusing on pharmaceuticals and food derivatives, found detectable levels of 13 such compounds. Only six of the 13 compounds were detected in Lake Mead, which was sampled twice, once in the spring and once in the summer. All 13 compounds were present in Las Vegas Wash at one time or another during six sampling periods spread throughout a year's cycle. Caffeine, cotinine, and 1,7 dimethylxanthine were the most widespread compounds detected. Cotinine is a metabolite of nicotine, which is present in tobacco products, and 1,7 dimethylxanthine is used in dietary and appetite suppressants. Caffeine increased its concentration in lake water from early spring to summer in response to recreational activity on Lake Mead. The low number of detections of these compounds in Lake Mead probably reflects the dilution factor within a large water body. The study also suggests that increased water temperature during summer months may amplify biodegradation (analgesics and anti-inflammatories) or biological uptake (antibiotics) of some of these compounds.

The effects of long-term exposure to low levels of individual or combinations of EDCs are being addressed through extensive research efforts in the United States and Europe. A potential non-health related problem is the negative effect that EDCs may have on bacteria beds used to purify water in wastewater treatment facilities.



## ***Current Mitigation Impact***

There are no regulations specifically aimed at EDC mitigation on the Colorado River system. The EPA has released preliminary reports discussing steroid and other EDC removal strategies from drinking water treatment processes. Results indicate that granular activated carbon adsorption and forms of biodegradation may be useful in removing some steroids, DDT, PCBs, endosulfan, methoxychlor, diethylphthalate, diethylhexylphthalate, and bisphenol A. The EPA is currently focusing on alkylphenolic compounds which result from wastewater treatment processes. Current technology can be employed to remove EDCs from both water and wastewater, as the need dictates.

## Summary

EDCs, including pharmaceuticals and personal care products, come from many different sources and represent many classes of chemical compounds. Limited work on the lower Colorado River system has detected the presence of a few of these compounds, and the issue of effects on overall human health remains uncertain. The detected compounds are predominantly antibiotics, prescription drugs, human waste metabolites, and pesticides.



## ***Recommended Solutions for Implementation and Funding***

Additional research is recommended to augment the limited data on the impact(s) of EDCs to humans and wildlife. Characterizing the occurrence of the compounds as well as the impacts will guide water managers to determine if EDC removal is warranted. The water industry will benefit from these studies, as this is a nation-wide issue, not just a local point of interest. Specific recommendations include the following:

- Perform a literature search and compile all available studies, reports, and data on EDCs in the ecosystem and their impacts. Identify opportunities to collaborate with on-going research teams such as University of Arizona, Arizona State University, Colorado School of Mines, University of California – Berkeley, Southern Nevada Water Authority, and WaterReuse Foundation.
- Characterize the occurrence of EDCs along the Colorado River by developing and implementing a Water Quality Sampling Program (WQSP) at selected locations including the following:
  - Up-gradient and down-gradient of sources of EDCs
  - Influent to water treatment plants
  - Recreational areas
- Prioritize issues identified from the reports on the literature search and WQSP to direct future research programs.
- Implement research programs to determine the impacts to humans as well as the ecosystem.
- Communities with household hazardous waste programs should provide education about the proper disposal of unused prescription medications and should accept unused prescription medications in their programs.

Funding sources for the WQSP include the US Environmental Protection Agency, Centers for Disease Control, AWWA Research Foundation, and Water Environment Research Foundation. Analysis of the data and studies specific to the ecosystem can be funded through US Fish & Wildlife Services, Wildlife Conservation Fund, the Heritage Grant Fund and ADEQs Waste Reduction Assistance Program.

 ***Action Plan for Implementation and Funding***

ADEQ is recommended to perform the literature search and to manage the WQSP by developing a program similar to *Perchlorate in Arizona; Occurrence Study of 2004*. Management would include utilizing the expertise of organizations skilled in collecting EDC samples and performing the analytical work, such as the US Geological Survey. ADEQ is recommended to assemble a team composed of the impacted stakeholders and selected experts to characterize and prioritize the salient issues based on the results of the two reports.



## Chapter 5

### Perchlorate

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### Pollutant Description

Perchlorate ( $\text{ClO}_4^-$ ) is a negatively charged ion composed of chlorine and oxygen. It combines with ammonium, potassium, or sodium ion to form perchlorate salts. Perchlorate salts have very low volatility, but high solubility. In addition, perchlorate sorbs poorly to mineral surface and organic material, which leads to high mobility in aqueous systems (i.e. surface water and groundwater).



### Sources

Perchlorate salts are naturally occurring or they can be man-made. Naturally occurring perchlorate is suspected in certain regions like the southern high plains of the Texas Panhandle. Detection of perchlorate in rain and snow samples suggests that a natural perchlorate background of atmospheric origin may exist. Man-made perchlorate salts, particularly ammonium perchlorate, is used by the military and aerospace industries as an ingredient in solid rocket fuels and propellants. Perchlorate is also found in explosives, pyrotechnics, blasting operations, dry batteries, and auto air bag inflators. There are other non-military/industrial uses and sources of perchlorate including use as a therapeutic drug in the treatment of thyroid disease, most notably hyperthyroidism associated with Graves disease, and in fertilizers derived from Chilean caliche, an ore containing nitrates. However, a 2001 survey of fertilizer composition conducted by the US Environmental Protection Agency (EPA) concluded that "fertilizer use would probably not be a major source of perchlorate contamination and would be possible only where fertilizers derived from Chilean caliche were used."



### Water Quality Impacts

Because of concerns about the possibility that perchlorate ingestion could interfere with thyroid function in a sub-group of the population (i.e., pregnant women with iodine deficiency), some scientists, health officials and the general public have recently questioned the safety of affected drinking water supplies, including the Colorado River.

### Current Regulatory Guidance

In January 2005, the National Academy of Sciences (NAS) issued a report on the health effects of perchlorate. It recommended a reference dose of 0.0007 milligrams per kilogram of body weight per day (mg/kg per day). In light of the NAS report, the U.S. Environmental Protection Agency (EPA) established 0.0007 mg/kg per day as the official reference dose for perchlorate in February 2005. EPA's reference dose represents a daily oral exposure level to the human population, including the most sensitive sub-groups, that is not expected to cause adverse health effects during a lifetime. At this time, EPA has not determined whether a drinking water standard, or Maximum Contaminant Level (MCL), for perchlorate is appropriate. If EPA decides that a perchlorate MCL is necessary, the agency may use this reference dose to establish the MCL. This regulatory process likely will take several years.

In the absence of a federal MCL, some states have already adopted or are in the process of adopting health goals for perchlorate. On March 11, 2004, California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA), adopted a Public Health Goal (PHG) of 6 ppb, and the state re-affirmed this PHG after the publication of the NAS report. More recently in August 2005, California's Developmental and Reproductive Toxicant (DART) Identification Committee, a panel of independent scientists administered by OEHHA, concluded that available scientific information on perchlorate was not sufficient for placing the substance on the Proposition 65 list of chemicals that cause birth defects or other reproductive harm. California Department of Health Services (DHS) is progressing towards establishment of an MCL in drinking water based on OEHHA's PHG.

Other states like Nevada and Arizona have similar cleanup levels or health goals for perchlorate. Nevada uses a perchlorate "provisional action level" of 18 ppb based upon interim guidance provided by U.S. EPA on June 18, 1999 and reaffirmed on January 22, 2003. Arizona established a Health Based Guidance Level (HBGL) of 14 ppb for perchlorate in drinking water. HBGLs represent concentrations of contaminants in drinking water that are protective of public health during long-term exposure. Both Nevada's cleanup level and Arizona's HBGL for perchlorate were established several years before the NAS study and EPA's subsequent adoption of the current perchlorate reference dose.

### **Colorado River**

In 1997, the Metropolitan Water District of Southern California discovered perchlorate in their water supply from the lower Colorado River. This discovery was made possible because of a new and more sensitive test method than was available in earlier years. The contamination was traced to Lake Mead and the Las Vegas Wash, and eventually to a Kerr McGee chemical plant in Henderson, Nevada. This finding prompted US EPA, the Nevada Division of Environmental Protection (Nevada) and Kerr McGee Chemical Company (Kerr McGee) to initiate immediate efforts to control the source and reduce perchlorate releases (mass loading) to the Las Vegas Wash.

Perchlorate-contaminated groundwater flows north about three miles from the Kerr McGee facility to the Las Vegas Wash. It is the most significant source of perchlorate entering the Las Vegas Wash. Prior to implementing any control measures, groundwater and surface water discharges to the Las Vegas Wash from all sources resulted in approximately 900 - 1,000 pounds per day of perchlorate loading. This load has been reduced to approximately 100 - 160 pounds per day by mid 2005.



## ***Current Mitigation and Remediation Efforts***

### **Control Strategy**

Kerr McGee, EPA, and Nevada cooperated in the development of a containment and remediation strategy for the Kerr McGee facility. The current strategy focuses on capture and treatment of perchlorate-impacted water at three discrete locations. The first location is at the Kerr McGee facility where perchlorate is most concentrated; the second is about midway between the facility and the Las Vegas Wash where there is a narrow subsurface channel that makes effective capture possible; and the third is proximate to the Las Vegas Wash where capture will have the most immediate impact on reducing the flow to the Las Vegas Wash. Each of these discrete locations reduces the load deposited into Lake Mead and correspondingly, the load present in the lower Colorado River.

In addition to the Kerr McGee facility, there is another contributing plume that is both smaller and much less concentrated. This plume, attributed to a former PEPCON perchlorate plant, is being investigated and will be remediated. American Pacific Corporation (AMPAC) is the parent corporation for PEPCON. In December 2002, AMPAC initiated a pilot study to determine the feasibility of an in-situ bioremediation (ISB) program to reduce perchlorate contamination. The ISB Pilot Study was successful in reducing perchlorate concentrations from about 500 parts per million (ppm) to less than 2 ppb. Nevada is requiring AMPAC to install a remediation system at the leading edge of its plume by the end of 2005. An ISB system will be installed and activated in two phases. The first phase is scheduled for activation by the end of 2005. The second phase will allow for activation of the full-scale long-term ISB system by early 2006.

### **Current Status**

The Kerr McGee control strategy has eliminated perchlorate-impacted groundwater from the facility. This has been achieved through the installation of a slurry wall (1,700 feet long and 60 feet deep) and 22 corresponding extraction wells. In 2004, these wells captured approximately 950 lbs/day of perchlorate. As of May 2005, nearly 940 lbs/day of perchlorate were removed by these wells.

The control strategy employed at the Athens Road Well field, the midpoint between the facility and the Las Vegas Wash consists of eight extraction wells, which began regular operation in October 2002. They capture residual perchlorate-impacted groundwater midway between the facility and the Las Vegas Wash. In 2004, these eight wells removed 760 lbs/day of perchlorate, or an estimated 90 - 98% of the mass flow approaching this well field. As of May 2005, monitoring data indicates approximately 775 lbs/day of perchlorate were removed.

The controls near the Las Vegas Wash, which consist of both surface water and groundwater capture via a seep intercept system and 10 wells, capture an estimated 70 - 90% of the mass flow. Amounts are decreasing and have dropped from about 500 lbs/day in early summer 2003 to about 190 lbs/day in 2004 and have continued to drop to about 150 lbs/day through the first half of 2005.

## **Lake Mead**

Perchlorate concentrations are monitored at two different locations in Lake Mead. Samples are taken from monitoring sites in Las Vegas Bay and near Saddle Island. Surface water sampling reveals seasonal variations from 10 - 100 ppb over the last five years. The sample values tend to peak in spring/summer and dip in the fall/winter, corresponding with the seasonal variations in water elevations.

Monitoring results at the Las Vegas Bay site showed no clear trend (except seasonal variation) from 2000 to 2003; summer time peak in 2004 shows a decrease of about 60% compared to 2002 and 2003.

At Saddle Island, concentrations began to decline in late 2003 and continued to decline through the first half of 2005. In late 2003, the monthly average peaks were 10.5 ppb, (about 35% lower than previous 3 year's peaks). In 2004, the monthly average concentrations ranged from 4.2 ppb to 4.7 ppb between July and November. The annual average for 2004 was 5.6 ppb, a decrease of about 40% from the 2003 annual average of 9.8 ppb, and a decrease of almost 60% from the 2000 annual average of 13.1 ppb. The Saddle Island monthly average perchlorate concentrations continue to show declines through the first half of 2005 as the groundwater remediation system operated by Kerr-McGee continues to limit the amount of perchlorate entering Las Vegas Wash and Lake Mead.

Since mid 2003, concentrations of perchlorate at Saddle Island in Lake Mead ranged from about 3 to 11 ppb. These levels are well below the EPA reference dose. EPA established a reference dose of 0.0007 mg/kg/day of perchlorate. This reference dose translates to a Drinking Water Equivalent Level (DWEL) of 24.5 ppb. A DWEL is the concentration of a contaminant in drinking water, including a margin of safety, which will have no adverse health effect. A DWEL is not a drinking water enforcement standard. These levels are less than the Nevada cleanup level and Arizona's HBGL.

## **Lower Colorado River**

The lower Colorado River is also sampled at two locations. The first location is below Hoover Dam at Willow Beach and is intended to measure perchlorate concentrations in water entering the Colorado River. Annual peak concentrations have declined gradually at this location from approximately 10 ppb to about 6 ppb in early 1999 to less than 4 ppb through the first half of 2005. According to the Nevada Division of Environmental Protection, the average annual concentrations continue to decline and have been reduced approximately 40% from 2000 to 2004. In 2005 this trend is continuing and perchlorate concentrations have declined to below 2.00 ppb in the last few months (1.8 ppb in July 2005 and 1.9 in August 2005).

The lower Colorado River is also sampled at the Colorado River Aqueduct at Lake Havasu. This site is intended to measure the perchlorate concentrations as they enter the southern California drinking water supply system. Here, peak concentrations also have shown gradual decline from 9 ppb to less than 4 ppb since control strategies were initiated in November 1999. In the 2004 sampling year, nine out of the twelve monthly samples were non-detect (Method 314 Reporting Detection Limit (MDL) = 4 ppb). All monthly samples for the first half of 2005 also have been non-detect using a 4 ppb detection limit.

For risk assessment purposes, all non-detect samples were recorded and graphed as 4 ppb. The average annual concentrations have been reduced approximately in half, from 6.4 ppb in 2000 to less than 4 ppb in 2004 and are expected to remain at less than 4 ppb throughout 2005.

Separate from the Kerr McGee cleanup efforts, the State of Arizona conducted a perchlorate occurrence study in 2004. Seventeen surface water samples along the lower Colorado River mainstem were taken. Sample results indicate perchlorate concentrations ranged from non-detect to 6 ppb. The study also concluded that there is a "slow, steady decline in perchlorate concentrations in both surface and groundwater along the Colorado River as well as in areas using Colorado River water in central and southern Arizona."

### **System Recovery**

It will take time for the groundwater and surface water system of the Las Vegas Wash through Lake Mead and into the lower Colorado River to recover from the mass loading that has occurred historically in this region. Even after the source of perchlorate is eliminated, it will require additional time for clean water to flush out the contaminated groundwater and surface water systems. Ongoing remedial efforts are reducing the perchlorate concentrations and mass. In an effort to estimate how long it would take Colorado River perchlorate concentrations to reach target levels under various perchlorate control strategies and hydrologic conditions (time necessary to flush the system), Flow Science, a consulting firm from Pasadena, California, was engaged by the Metropolitan Water District of Southern California (MWD) to provide a predictive tool for MWD to understand how perchlorate concentrations in the lower Colorado River could be expected to decline over time. Flow Science conducted a perchlorate modeling effort and presented a final report in March 2004. Assuming 90% of all perchlorate sources to Las Vegas Wash are captured by October 2002, the modeling predicted that perchlorate concentrations at the Colorado River Aqueduct intake (where California sources its water from the Lower Colorado) would reach 4 ppb by mid-2004 and 2 ppb by mid-to late-2005. The modeling predictions have been borne out to date by the 2004 annual average concentration at this location which was less than 4 ppb, the consistent set of sample results demonstrating concentrations at this location have remained less than 4 ppb since June 2004, and the July and August 2005 Willow Beach concentrations which are less than 2 ppb.

### ***Recommended Solutions for Implementation and Funding***

Current efforts to reduce perchlorate concentrations in the Colorado River should continue. These include the industry and government efforts to arrest and mitigate the sources of perchlorate which migrate to Lake Mead and the Colorado River through the Las Vegas Wash. These ongoing efforts continue to reduce the levels of perchlorate in the Colorado River.

### ***Action Plan for Implementation and Funding***

Appropriate containment, control and cleanup efforts have been and are being implemented and are improving the River. Consistent with the recommendation in *Perchlorate in Arizona Occurrence Study of 2004*, the State of Arizona is encouraged to continue monitoring the cleanup and mitigation efforts of the Colorado River.



## Chapter 6

### Bacteria and Pathogens

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## Chapter 6 - Bacteria and Pathogens



### Introduction

Bacteria are microscopic organisms that have existed for a very long time. Geologic record shows bacteria to have existed 3.2 billion years ago. Some researchers believe that the first oxygen that appeared on Earth, 2 billion years ago, was created by bacteria. The discovery of bacteria in 1676 is credited to Antony van Leeuwenhoek. In 1876 it was discovered that bacteria could cause disease.

Bacteria are very diverse and many can multiply quickly depending on surrounding conditions. Some bacteria are extremely hearty and can remain dormant while conditions are not good. Still other bacteria can be carried in the air. Bacteria are at the bottom of the food chain and are known as decomposers. They play a very important role in recycling organic materials that plants and animals need to survive. There is a proportional tie between nutrients, sediments and bacteria that should be recognized. Because bacteria are living organisms that have a preferred habitat, more nutrients and/or more sediment probably means more bacteria.

The human body is home to many kinds of bacteria. Bacteria can cause disease two ways. First, the bacteria can multiply itself inside the human or animal body and second, it can produce a toxin which makes the victim ill.



### Pollutant Description

Coliform bacteria are a large group of bacterial species and are most commonly associated with water quality. The group includes both fecal coliform and non-fecal coliform. Fecal coliforms can include disease-causing and non-disease causing species. *Escherichia coli* (*E. coli*) is one species of fecal coliform bacteria present in the fecal matter of warm blooded animals. *E. coli* is used in water quality sampling as an indicator of fecal contamination and the potential presence of other harmful organisms.

One other form of bacteria worth mentioning here is *cyanobacteria*. Cyanobacteria were once mistaken for blue-green algae; however, further research suggested that the composition of cyanobacteria did not agree with the make-up of algae. Cyanobacteria have been shown to cause toxic blooms in freshwater. They produce toxins that can be very harmful to animals and possibly, to humans. Cyanobacteria have been implicated as a likely cause of fish kills in freshwaters. The two most likely pathogens that will be found in recreational waters are *Cryptosporidium* and *Giardia*.

According to the CDC, cryptosporidium is a parasite that lives in the intestine of animals and humans. It is able to live outside the body for extended amounts of time and is



**Figure 6-1:** Above is a picture of fecal coliform bacteria.

very resistant to chlorine disinfectants. *Cryptosporidium* is now recognized as one of the most common sources of disease in drinking and recreational water in the United States and the world.

CDC describes *Giardia* as a one-celled parasite that lives in the intestine of both animals and humans. Like *Cryptosporidium*, *Giardia* can live outside the body for a very long time. It, too, is found all over the world and has become known as one of the most common sources of waterborne disease.

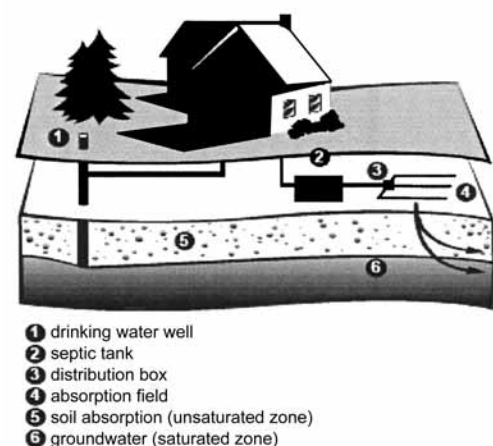
## Sources

All natural water (rivers, lakes, wetlands) contain bacteria. Ground water usually has fewer bacteria than surface water because of its long travel time in the sub-surface environment. However, ground water can become contaminated by sewage –via septic systems or sewer outfalls, fertilizer and surface runoff, as well as other pollution sources. Potential sources in Arizona include high density of on-site wastewater systems, storm water run-off from the monsoons during the summer and rain/storms during the winter and inadequate number of sanitary facilities in recreational areas along the Colorado River. Bacterial contamination is an issue that is linked with high concentrations of people and animals, whether it is recreational or residential.

Some of the communities along the Colorado River were developed with the use of on-site wastewater systems. As discussed in Chapter 2 on Nutrients, in the past few years, communities such as Bullhead City and Lake Havasu City have been sewerage their cities in order to avoid bacterial and other contamination of the River. Effluent from a septic system may have bacteria which then has the potential of contaminating the ground-water (see Figure 6-2). Wastewater treatment plants also have potential for contaminating the River via release of untreated effluent due to a failure in the treatment system or a broken pump or line.

Several communities do release effluent directly into the Colorado River including, both Laughlin and Las Vegas, Nevada. Moreover, Las Vegas, Henderson and Clark County, Nevada, has proposed to discharge substantially increased quantities of effluent (up to 450 million gallons per day) into Lake Mead. This is treated effluent; however, the risk remains for a break in the system which could result in detrimental effects on the river.

Storm water run-off also occurs when enough rain falls to cause flow. With the large drainages and washes that dot the Arizona desert, the potential for bacterial contamination of the River is present. During these events, the storm water runs over and mixes with organic material that is available in the washes and drainage areas. The drainage patterns are constantly changing with the explosive development along the Colorado River. Each time the drainage pattern changes, a new set of challenges are encountered. It should be



**Figure 6-2:** Diagram of how effluent eventually enters the groundwater.

noted that the Bill Williams and Gila Rivers are the only perennial tributaries in the lower Colorado River that can introduce substantial flood influence on the main stem Colorado.

Recreational activity along the Colorado River also increases bacterial contamination potential. With inadequate numbers of sanitary facilities (both restrooms and trash facilities), tourists and recreationalists will consistently contaminate the shoreline of the River. Trash along the shoreline of Lake Havasu has increased substantially over the last several years as evidenced by the volume collected. When sanitary facilities are not available, those using the River will contaminate the shoreline with trash (containing all matter of material including diapers) and excrement which is eventually washed into the River. Potential for pollution also exists due to the boat pumping stations along the River. Any malfunction at these stations could introduce bacteria to the River again.

## ***Water Quality Impacts***

### **Health Issues**

Elevated levels of bacterial and protozoan contamination in the Colorado River may cause a variety of illnesses including, but not limited to, E. coli, cholera, shigella, salmonella and campylobacter. According to the CDC, each year an estimated four billion diarrheal episodes occur and an estimated two million deaths, the majority of which occur in third-world countries, with a smaller percentage occurring here in the United States. CDC believes that at least half of these illnesses and deaths are a result of waterborne diseases. The symptoms of the diseases caused by contaminated water include nausea, vomiting, diarrhea (bloody and/or dehydrating), and in some cases, death. Animals are also susceptible to becoming ill from contaminated water. Sickness and death may occur in both humans and animals due to both enterobacteria (E.coli, etc.) and cyanobacteria found in the Colorado River.

### **Water Quality Testing**

Bacterial testing of water quality along the Colorado River has been taking place. Each summer Lake Havasu is tested a minimum of twice per month at carefully selected beaches for bacterial counts. When a limit is exceeded, the water is tested once again, within 24 hours. It is the policy of Mohave County that if the second test results in an exceedance the affected beach is posted and closed. The Arizona Department of Environmental Quality (ADEQ) has also contracted with USGS in order to conduct periodic testing along the Colorado River for bacterial levels along with other contaminants.

### **Bacterial Concentrations in the Colorado River**

Several agencies test the River's water quality. Agencies involved in testing include ADEQ, Mohave County Department of Public Health, USGS, National Park Service, the State of Nevada and sometimes, Indian Health Services. Although there have been a few recorded spikes in bacterial testing along the Colorado River, specifically, in Lake Havasu, follow-up testing has not indicated a chronic problem. However as development and recreation along the River continues, potential for increase of bacterial contamination will continue.



## ***Current Mitigation Efforts***

As stated earlier, a few communities along the Colorado River are beginning or have been sewerage their cities and reducing the number of septic tank and leach field systems due to contamination of groundwater and future concerns that the groundwater could no longer be drinkable or useable.

There has been a concentrated effort to eliminate old privies in the Lake Havasu area of Mohave County and replace these units with more sanitary restroom facilities. As part of this effort, there have been several new restroom facilities added to beaches along Lake Havasu. Trash containers have also been added to aid in the collection of refuse and items such as dirty diapers which would have, in years past, eventually been washed into the lake. This effort at trash collection has met with limited success.

Lake water sampling and sampling along the Colorado River continues to take place and procedures are in effect which prevent swimmers from entering water that is deemed unhealthy for recreating.

Mohave County is preparing to propose a local ordinance that will require more homes along the Colorado River to connect to sewage treatment plants. This area is known for having very shallow groundwater and sandy soils which makes for a very difficult area to install septic systems. Although the communities of Lake Havasu and Bullhead City have taken great strides towards connecting to community sewer, the county area in between these communities is still installing septic systems.

The National Park Service (NPS), on September 21, 2005, issued a press release which indicated that an Environmental Assessment for the Replacement of Water and Sewer Systems had been released for the Lake Mead National Recreational Area. According to the referenced press release, the systems are extremely old and in need of constant maintenance.

Along the lines of sanitation, in March of 2003 the NPS published their Lake Management Plan/Final Environmental Impact Statement for the Lake Mead National Recreation Area. This plan addresses sanitation issues and proposes rules requiring all overnight boating campers to possess a portable toilet and to prohibit the use of glass and Styrofoam containers. The NPS recognizes that education and proper notification of campers and visitors is an integral part of this process.



## ***Recommended Solutions for Implementation and Funding***

- Coordinate a monitoring network operated and maintained to improve data gathering and analysis efforts to identify hot spots or periods of violation, pursue remedies and keep the feedback loop going perpetually, aiming to always improve efficiency. One way to begin this would be a concentrated survey along the River in areas of high use and during busy seasonal periods. The monitoring network should include all agencies that currently conduct surface water testing along the Colorado River and interested stakeholders. Regular communication among the monitoring network is recommended.

- ADEQ should support local jurisdictions as they aim to pass local ordinances requiring abandonment of on-site wastewater systems along the Colorado River. This would not require any extra funding on the part of the State.
- Installation and maintenance of more sanitary facilities along the Colorado River to include restrooms, trash locations and educational materials such as signage. This may require more substantial funding.
- ADEQ and other officials should closely monitor the proposal by Las Vegas, Henderson and Clark County, Nevada, to discharge up to 450 million gallons a day of treated effluent directly into Lake Mead.
- Environmental education beginning in schools and expanding to community service groups, etc. Public Service Announcements conducted in association with education.

### ***Action Plan For Implementation and Funding***

Action plan for the above-mentioned recommendations:

- ADEQ should dedicate resources to coordinate a monitoring network on the mainstream of the Colorado River. ADEQ should survey existing monitoring activities and review and prioritize the establishment of future monitoring in coordination with interested federal and local agencies. Monitoring network to produce quarterly monitoring data reports.
- Conduct research to find what potential funding sources (grant programs) are available for water quality projects. City Councils/local jurisdictions approached for recommendations on what local groups could help with in this type of activity (e.g. "Keep Havasu Beautiful"). ADEQ continue to encourage applications to the Water Quality Improvement Grant Program for eligible sanitary facilities and education along the River.
- Local governments along the River may apply for grant with Legacy Foundation for educational grant-funded program.
- Support the effort of the Colorado River Regional Sewer Coalition to obtain federal funding for sewer infrastructure projects in communities along the Colorado River.



## Chapter 7

### Salinity/Total Dissolved Solids

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## Chapter 7 - Salinity/Total Dissolved Solids

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### Pollutant Description

For purposes of this report, the terms “total dissolved solids” and “salinity” will be equivalent, although there are slight differences between the two:

- “Total dissolved solids” (TDS) are generally associated with freshwater systems and consist of inorganic salts, small amounts of organic matter, and dissolved materials.
- Salinity was originally an oceanographic term, generally describing the total salt content, but is also used for freshwater systems.

Both terms are used to describe the sum of the inorganic cations and anions dissolved in water: sodium, potassium, calcium, magnesium, carbonates, chlorides, sulfates, and nitrate.

The saline sediments of the Colorado River Basin were deposited in prehistoric marine environments. Sedimentary rocks are easily eroded and dissolved, transporting their salts into the river system. Human activities such as irrigated agriculture and energy exploration can influence and accelerate this process (Colorado River Basin Salinity Control Forum, 2002).

Increased salinity levels in the Colorado River affect agricultural, municipal and industrial users. Agricultural water users suffer economic damage due to reduced crop yields, added labor costs for irrigation management and added drainage requirements. Urban users must replace plumbing and water-using appliances more often, or spend money on water softeners or bottled water. Industrial users and water and wastewater treatment facilities incur reductions in the useful life of system facilities and equipment (Colorado River Basin Salinity Control Forum, 2002). Damages in the United States are estimated at \$330 million per year, and economic damage in Mexico is not quantified but also a significant concern (Department of the Interior, 2003).

### Water Quality Standards

#### *Surface Water*

In 1972, EPA required development of water quality standards for salinity in the Colorado River in accordance with Clean Water Act (CWA) Section 303. The seven Colorado River basin states formed the Colorado River Basin Salinity Control Forum (the Forum) in 1973. The Forum has been the vehicle that has allowed the states to cooperate in developing the standards which included numeric criteria at three locations in the lower Basin as well as a basin-wide plan of implementation. The seven states each adopted the standards and plan of implementation through their individual administrative processes, and the standards were approved by EPA. The implementation of the salinity control plan has ensured compliance with the numeric criteria while the Basin states have committed to develop the water allocated to them by the Colorado River Compact.

Arizona's Surface Water Quality Standards establish a flow-weighted average annual salinity standard that must be maintained on the lower Colorado River at the following locations:

<b>Arizona Colorado River Salinity Standards</b>	
<b>Location</b>	<b>Salinity</b>
Below Hoover Dam (to Parker Dam)	723 mg/L
Below Parker Dam (to Imperial Dam)	747 mg/L
At Imperial Dam	879 mg/L

These standards were established by the Forum based on data collected in 1972, and the conditions present in 1972 became the standard to be attained for the future. The Forum emphasizes that this should not create any inference that 1972 represents a typical year from either a hydrologic or water quality perspective. Rather, the purpose of the numeric criteria and the Forum's Plan of Implementation for Salinity Control is to mitigate the effects of water resource development and human activities in the Colorado River Basin after 1972. The Plan is not intended to address human-caused salinity prior to this date. The standards are also not intended to address any other designated uses of the Colorado River (human health and aquatic and wildlife); however, the Forum states that projected future salinity concentrations, with or without salinity controls, have not been shown to have adverse effects on human health or wildlife (Forum, 2002).

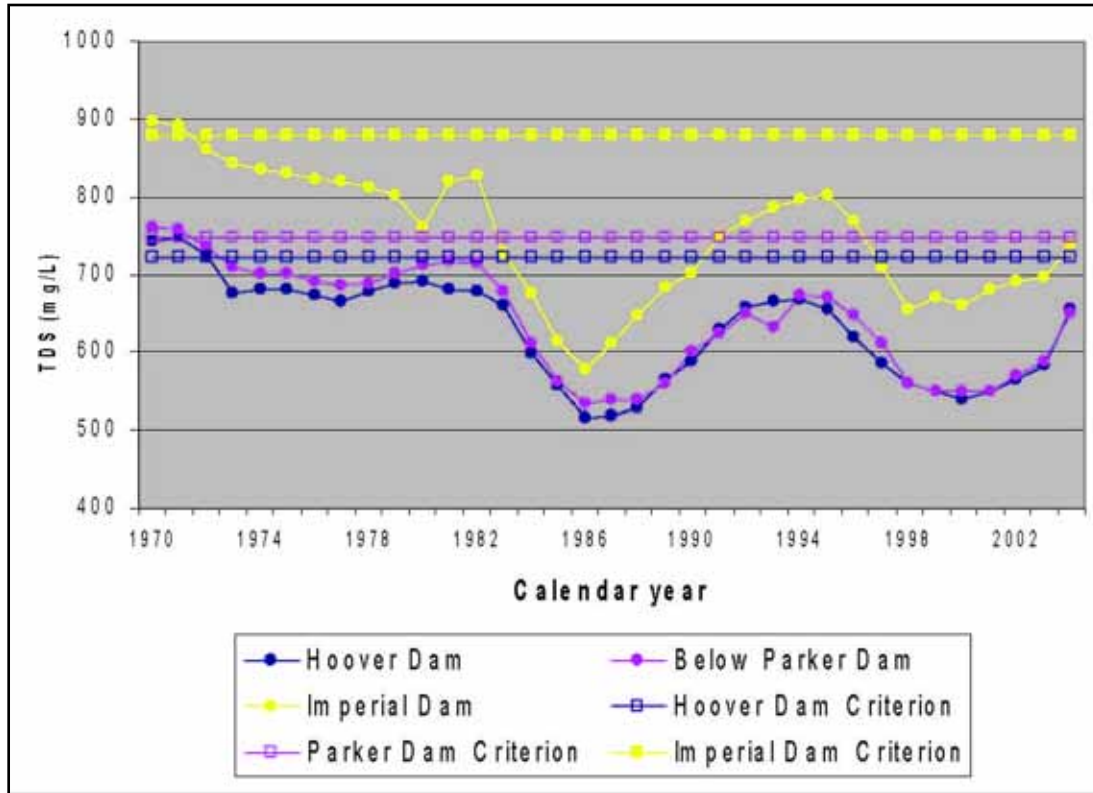
Impacts of natural variations in the hydrologic cycle have a significant impact on salinity levels. Therefore, the Forum's plan for maintaining the criteria is developed using a long-term mean annual water supply of 15 million acre-feet per year at Lee's Ferry, Arizona. When River flows are at or above this level, concentrations are typically below the numeric criteria. Conversely, when flows are significantly below the long-term mean, and reservoirs are depleted, salinities are expected to increase (Forum, 2002). Fluctuating salinity levels are shown in Figure 7-1.

The diluting effect of record high flows during the mid-1980s caused lower salinity levels, followed by an extremely dry period from 1988 to 1992 with rising salinity concentrations. Moderately high flows later in the 1990s once again resulted in decreasing salinity. Recognizing the effects of variable hydrologic cycles, the Forum considers natural increases to be in conformance with standards, provided that concentrations are at or below the criteria when river flows and reservoir conditions return to normal. Federal regulations also allow for temporary increases due to additional water development projects until salinity control projects are brought on line (Forum, 2002).

### ***Groundwater***

There is no salinity standard for groundwater quality in Arizona; however, EPA has recommended a Secondary Maximum Contaminant Level (SMCL). SMCLs are non-enforceable, aesthetics-based guidelines that define the maximum concentration of a contaminant that can be present without imparting unpleasant taste, color, odor or other aesthetic effect on the water. See Figure 7-2.

Figure 7-1: Salt Concentrations at Numeric Criteria Stations expressed as annual flow-weighted averages



\*see Appendix 4 for data used to create this graph and explanation of flow-weighted average calculations.

Table 7-1: EPA's SMCLs for Public Drinking Water Systems	
Pollutant	SMCL
Total dissolved solids	500 mg/L
Sulfate	250 mg/L
Chloride	250 mg/L

## Sources

The Department of the Interior (2003) along with other members of the Colorado River Basin Salinity Control Forum have spent 30 years investigating sources of salinity and have identified the following major sources:

**Natural Sources** - Nearly half of the salinity in the Colorado River system is from natural sources. Saline springs, precipitation runoff, and associated erosion of saline geologic formations all contribute to this background salinity. The erosion process and associated salinity problems can be accelerated by human activities such as grazing and energy exploration and development.

**Irrigated Agriculture** - Agriculture is the largest user of water in the Colorado River Basin, and agricultural return flows contribute to the salinity of the system. Irrigation water dissolves salts found in the underlying saline soils and geologic formations, usually marine shale. Deep percolation mobilizes these salts found naturally in the soils, especially if the lands are over irrigated.

Groundwater quality often deteriorates in arid irrigated areas due to salt buildup as a result of evaporation and evapotranspiration. The portion of irrigation water that is actually consumed by plants or lost to evaporation is virtually free of salts, therefore, the vast majority of salts in the original irrigation water percolate through the soil, eventually to recharge the underlying aquifer. This contaminated groundwater is then pumped for irrigation use and will percolate to the underlying aquifer again. Thus, the recycling of groundwater will continue to increase dramatically the salinity of the aquifer over time. As the salinity of the groundwater increases, so too does salinity of surface water in the Colorado River as irrigation tail waters flow back into the River.

**Development of Energy Resources** - The development of coal, oil and gas, and oil shale, also contribute significant quantities of salt to the Colorado River. The Forum recognizes that the salinity of surface water can be increased in these operations through the following means:

- Mobilization of saline groundwater - There are many static, saline aquifers located throughout the Colorado River Basin confined within impermeable shales, which have prevented the transport of their saline water. Drilling and mining can provide a path for the saline aquifer water to reach the surface.
- Mineral dissolution and uptake in surface runoff – The location of fossil fuels is associated with marine-derived geology. Any disturbance to the land increases contact surfaces and allows water to dissolve previously unavailable minerals.
- Production of saline water – Oil and gas production in the Basin can produce saline water in amounts several times greater than the amount of oil produced, depending upon the geology of the area. Disposal techniques include evaporation, injection and discharge to local drainages.
- Consumption of higher quality water – Consumption during energy development can reduce the amount of water available to dilute Colorado River salinity.

**Municipal and Industrial Sources** - Municipal and industrial users contribute some additional salinity, though the Forum estimates the relative amount is small (about 1% of the salt load). The use of residential water softeners can contribute salt to wastewater, and if untreated, result in saline discharge from treatment plants that discharge to the Colorado River.

**Plant Growth** - Excess dissolved solids negatively impacts plant growth. As shown in Table 7-2 below, as salinity increases above 500 mg/L, the effects on crops increase, reducing agricultural production. Above 500 mg/L, crops that are sensitive to salinity cannot be grown. Rapid salinity changes can cause changes in osmotic pressure, resulting in plasmolysis (cell shrinkage) of tender leaves and stems. In addition, sodium is toxic to certain plants, especially fruits, and frequently causes problems in soil structure, infiltration and permeability rates. Clay soils, with their high percentage of exchangeable sodium, will swell when wet and can further limit water movement and plant growth.

In its Water Quality Report, the Salt River Project (SRP, 1998) references guidelines for total dissolved solids (salinity) and its separate constituents in water used for agricultural irrigation purposes. These general guidelines can be applied to Colorado River water to evaluate its suitability for use based on salinity concentrations.

**Table 7-2: SRP Dissolved Solids Guidelines for Agricultural Purposes**

Parameter	Effects on crops	Range of concentrations		
		No Problems (mg/L)	Increasing Problems (mg/L)	Severe Problems (mg/L)
TDS	General effects on crop yield	< 500	500 – 2000	> 2000
	De-flocculation of clay and reduction in infiltration	> 320	< 320	< 128
Sodium	Effects when water is absorbed by leaves	< 69	> 69	--
Chloride	Effects when water is absorbed by roots	< 142	142-355	> 355
Chloride	Effects when water is absorbed by leaves	< 106	> 106	--
Bicarbonate	Effects when water is applied by sprinklers (causes white deposits on fruits and leaves)	< 90	90-520	> 520

\* Deflocculation refers to the dispersion of clay particles that occurs when the positive charges of the clay particles are covered and attractive forces are greatly reduced. This process results in reduced soil permeability.

**Drinking Water** - In the *Quality Criteria for Water*, 1986, the US Environmental Protection Agency (EPA) indicates that excess dissolved solids are objectionable in drinking water because of possible physiological effects, unpalatable mineral tastes and higher costs. These increased costs are caused by corrosion and encrustation of metallic surfaces and the necessity for additional treatment. Primary maximum contaminant levels for TDS and associated anions and cations have not been set for drinking water, because they do not present a human health concern for the general public.

**Infrastructure Damage** - High salinity levels mean that water users must replace plumbing and water-using appliances more often, or spend money on water softeners or bottled water. Industrial users and water and wastewater treatment facilities incur reductions in the useful life of system facilities and equipment (Colorado River Basin Salinity Control Forum, 2002).

## **Current Mitigation Efforts**

In 1974, Congress enacted the Colorado River Basin Salinity Control Act which authorized the construction, operation, and maintenance of salinity control works throughout the Basin. Title I of the Act addressed the US commitment to Mexico regarding the quality of water deliveries to Mexico pursuant to the Treaty of 1944. It authorized the construction and operation of a desalting plant located in Yuma, brine discharge canal and other features to ensure that the average salinity concentration of water delivered to Mexico does not exceed 115 parts per million (ppm), plus or minus 30 ppm, above the annual average salinity at Imperial Dam (US Department of the Interior, 2003).

Title II of the Act created the salinity control program, which has allowed for the construction of salinity control projects by both the Bureau of Reclamation (BOR) and US Department of Agriculture (USDA) that have resulted in more efficient use of water. It also directed the Departments of Interior and Agriculture and the EPA to manage salinity, including salinity contributed from public lands. BOR's Basinwide Salinity Control Program is now open to allow competition and has reduced the cost of salinity control from approximately \$70 per ton to \$30 per ton (US Department of the Interior, 2003).

Since the 1970s, the Department of the Interior, through BOR, has been working with USDA, the Bureau of Land Management (BLM), and the Forum to build and operate cost effective salinity control projects on the Colorado River. Irrigation improvements allow for better water management that reduces deep percolation and the transport of shallow salt-laden ground water back to the river system. Point sources are controlled by Forum policy and the Nation Pollutant Discharge Elimination System (NPDES) program, when the source is from man-induced discharges, and by various means when the source is from saline springs. One unique project is the Paradox Valley project where BOR collects brines that were discharging into the bed of the Dolores River in southwestern Colorado and injecting those brines into a 16,000 foot injection well. This project accounts for about 20% of the salinity control to date.

The Central Arizona Salinity Study (CASS) was initiated in 2001 by the US Bureau of Reclamation in a partnership with several major municipal water providers located in central Arizona. The purpose of CASS was to identify and evaluate salinity issues in central

Arizona. Phase 1 concluded that 1.5 million tons of salt per year are imported into the Phoenix metropolitan area with 1.1 million tons per year accumulating in the area. Likewise, 130,000 tons of salt per year are imported into the Tucson area with an accumulation of 107,000 tons per year. The Tucson figures are expected to increase over time as the amount of Colorado River water imported into the Tucson area increases (US Bureau of Reclamation, 2003).

The economic impacts of increased salinity in the raw water supplies of central Arizona are significant in absolute terms, primarily in the Phoenix area. The main concern is that increased concentrations of salinity in treated wastewater effluent may result in limiting the future reuse of this important future source of water supply in central Arizona. While the technology exists to desalt the surface water supplies in central Arizona, the cost of implementing these technologies, at the present time, is greater than the economic costs associated with the increased salinity levels. Moreover, the nature of the technologies involved results in a net loss of 20 percent to 30 percent of the raw water. On a preliminary basis, CASS Phase II has concluded that management of salinity discharges into the sanitary sewer system at the wastewater treatment plant, public education of how water users can voluntarily reduce salinity, and additional consideration of localized treatment of brackish groundwater is warranted. CASS has also strongly endorsed the continued implementation of the salinity control projects funded through Title II of the Colorado River Basin Salinity Control Act of 1974.

The Forum continues as a working group to provide interstate and interagency coordination and guidance for the salinity control program to ensure that those projects which are the most cost-effective be given preference for funding, as directed by the Colorado River Basin Salinity Control Act. The Department of the Interior issues regular progress reports with detailed descriptions of mitigation efforts throughout the basin. These reports should be consulted for further information.

The Forum also reviews the numeric salinity standards on the Colorado River every three years. In 2002, it concluded that the standards provide protection from long-term increases in economic damage to downstream uses. However, even current levels of salinity are cause for concern. A study conducted by BOR and the Metropolitan Water District of Southern California estimates salinity damage in Arizona, California and Nevada to be nearly \$200 million per year at the 1999 salinity level of 669 mg/L. They estimate this would increase to \$500 million per year if salinity were allowed to return to the level of the numeric standard at Imperial Dam (879 mg/L).

The 2002 review also cautions that water use patterns have begun to shift in the lower mainstem of the River. Within the agricultural sector, there has been a shift to growing more vegetables which are less salt tolerant. Basin states also indicate there will be a continued shift from use by the agricultural sector to the municipal and industrial sector. They predict more pressure in the future to reduce salinity levels even further.

The Bureau of Reclamation, who oversees the Salinity Control Program, indicates that:

- Salinity control measures installed with USDA assistance control over 300,000 tons of salt annually. Measures installed with Bureau of Reclamation assistance control nearly 500,000 tons each year.

- The Natural Resources Conservation Service (NRCS) currently uses the Environmental Quality Incentives Program (EQIP) funds to implement on-farm salinity control measures in six project areas in western Colorado, eastern Utah, and southwestern Wyoming.
- The Forum has adopted policies for salinity criteria for municipal and industrial discharges (see Appendix 5).

## ***Recommended Solutions for Implementation and Funding***

Treated municipal wastewater can contain significant amounts of total dissolved solids. As the growth in population continues to increase in the Colorado River region, the amount of treated effluent discharged to the River will increase. The State of Arizona should continue monitoring effluent discharges to the River and their potential effects as a source of increasing salinity. Arizona Pollutant Discharge Elimination System (AZPDES) or NPDES permits authorizing surface water discharges to the Colorado River should be consistent with the Forum policy entitled “NPDES Permit Program Policy for Implementation of Colorado River Salinity Standards,” (see Appendix 6) adopted in October 2002 (Forum, 2002).

In its 2003 Progress Report, the Department of the Interior concluded that the Salinity Control Program has successfully controlled 800,000 tons of salt per year. However, to meet the target of 1.8 million tons per year by 2020, additional funding will be needed to implement new salinity control measures that will remove approximately 59,000 additional tons each year. The review identifies the following capital funding needed to meet this goal:

- BOR appropriation – \$10.5 million per year, bringing the total Reclamation program with cost-sharing to \$15 million per year.
- USDA EQIP appropriation – \$13.8 million per year, bringing the total on-farm program to \$19.7 million per year with Basin states parallel program.
- No new measures for BLM were proposed due to questions raised regarding verification of rangeland salinity control. When measures are identified, they will be included in the Salinity Control Program and would reduce the amount of salinity control and funding needed for BOR and USDA projects.

Implementation of the Title II salinity control program has been a documented success in preventing salinity from increasing beyond 1972 levels. The projects and control measures which have been implemented are responsible for the decrease in salinity concentrations in the lower Basin while significant new growth has occurred. However, federal spending cuts have reduced the Bureau of Reclamation’s efforts to implement the rest of the Title II program.

Most of the salinity control measures are implemented in the upper Basin states. However, it is important for the State of Arizona, working with the other Basin states and the Forum, to continue to encourage the President and the US Congress to fully fund Title II so that the program continues to be implemented as originally intended.

 ***Action Plan for Implementation and Funding***

The Forum develops action plans for implementation and funding on a regular basis, and should be consulted for further information.



## Chapter 8

### Sediment and Suspended Solids

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## Chapter 8 - Sediment and Suspended Solids

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### Pollutant Description

Suspended solids consist of organic (algae and other biological matter) and inorganic (sands, silts, etc) particulates held in water.

Sedimentation occurs when wind or water runoff transports soil particles from land surfaces and deposits them in a waterbody. As the energy and flow of a stream decreases, the amount of particulates that a water column can hold decreases and particulates drop to the stream or lake bed. Changes in channel form, such as streambank stability and amount of stream sinuosity (curves or turns), can also increase sedimentation (aggradation) or erosion (degradation).

### Water Quality Standards

**Suspended Sediment Concentration (SSC)** – Arizona adopted a surface water quality standard for suspended sediment concentration (SSC) in 2002 to protect fish populations. This is the dry weight of sediment from a known volume of water-sediment mixture. It is applied only to flowing waters (perennial and intermittent streams). It does not apply to lakes, ephemeral streams or waters classified as effluent dependent waters. It does not apply during runoff events. The SSC standard states:

*The geometric mean of a minimum of four Suspended Sediment Concentration samples cannot exceed 80 mg/L. The standard applies to a stream that is at or near base flow and does not apply to a stream during or soon after a precipitation event (A.A.C. R18-11-109(D)).*

**Narrative Bottom Deposits Standard** – Whereas the SSC standard addresses sediment suspended in the *water column*, the narrative bottom deposit standard is intended to prevent excessive *bottom deposits* of sediment in amounts that adversely affect aquatic life. It states:

*A surface water shall be free from pollutants in amounts or combinations that settle to form bottom deposits that inhibit or prohibit the habitation, growth, or propagation of aquatic life A.A.C. R18-11-108(A)(1)).*

**Proper Functioning and Condition of Riparian and Wetland Areas** – Riparian vegetation is very effective in reducing sediment and suspended solids, by increasing deposition before runoff water reaches a surface water (Engineering Science, 1994). Greater plant density means more suspended sediments can be removed. The Bureau of Land Management, in conjunction with the US Forest Service, developed a field protocol known as “proper functioning and condition of riparian and wetland areas” to assess whether a riparian-wetland area is functioning properly in terms of vegetation, landform and amount of large woody debris present to dissipate stream energy associated with high water flows. A properly functioning riparian area will reduce erosion, filter and capture sediment load, and aid in floodplain development. It has additional benefits including providing good wildlife habitat and facilitating groundwater recharge. While federal

agencies use this visual-based qualitative tool to assess long stream reaches, ADEQ uses this information as supporting evidence when assessing a stream's physical condition.

**Turbidity** – ADEQ repealed its turbidity criteria in 2002 because it is a surrogate measurement for estimating the amount of suspended particles in water. Although no longer an enforceable standard, the old turbidity criteria can be used as a guideline to evaluate suspended particles in water. Turbidity is measured in terms of nephelometric turbidity units (NTU), which is an index of light refraction when light strikes suspended particles in water. For reference, the following old turbidity criteria were established to protect aquatic life and wildlife:

	Rivers, streams, and other flowing water	Lakes, reservoirs, and other non-flowing water
A&W warmwater fishery (below 5000 ft. elevation)	50 NTU	25 NTU
A&W effluent-dependent water	50 NTU	25 NTU
A&W coldwater fishery (above 5000 ft. elevation)	10 NTU	10 NTU

In the Colorado/Grand Canyon Watershed, the following segments are impaired due to suspended sediment concentrations in excess of water quality standards: the Colorado River from Parashant Canyon to Diamond Creek, the Paria River from the Utah border to the Colorado River, the Virgin River from Beaver Dam Wash to Big Bend Wash. In the Little Colorado River Watershed, the Little Colorado River from Porter Tank Draw to McDonalds Wash is impaired due to suspended sediment concentrations in excess of water quality standards.

## Sources

There has not been a detailed study of sediment sources along the Colorado River. However, several likely sources can be identified. Natural stream erosion, in the absence of human activities, is affected by water flow and channel morphology, in combination with type of catchment bedrock, soil profiles and vegetation (Leopold et al, 1964). Arizona's arid conditions, relatively low plant coverage and erodible soils make some degree of suspended solids and sedimentation a natural phenomenon in the state. Natural sources of suspended solids may be difficult to control.

Human activities increase suspended sediment loads beyond natural background levels. The causes of excess sediment in streams are similar across the country: urban runoff, construction/development, agriculture and forestry are the largest contributors. In the arid Southwest, wildland fires, grazing and off-highway vehicle use must also be considered. How these sources contribute sediment in the Colorado River Watershed is summarized below.

## **Construction and Urban Runoff**

The construction of buildings or roads can result in soil loss and sediment transport to nearby surface waters (Waters, 1995). Much of the Colorado River watershed in Arizona would not be considered urbanized; however, there are several cities between Lake Mead and Arizona's border with Mexico. Other areas, while not "urbanized," have been developed for vacation homes. Urban runoff and construction should be considered a probable source of some sediment.

Nationally, in urban areas, suspended solids constitute the largest volume of pollutant loadings. Nonporous urban landscapes, such as roads, bridges, parking lots, and buildings prevent runoff from percolating slowly into the ground. Water remains above the surface, accumulates, and runs off in large amounts, usually carrying large loads of sediment with it (<http://www.epa.gov/owow/nps>).

Further contributing to the problem are stormwater systems that channel runoff from roads and other impervious surfaces (<http://www.epa.gov/owow/nps>). In Arizona, torrential monsoon events can produce large volumes of storm flow runoff which, when the stormwater enters the stream channels, can erode streambanks and remove protective streamside vegetation. This erosion contributes sediment to the streambed.

## **Agriculture and Grazing**

When agricultural lands are not properly managed for soil erosion, excessive amounts of sediment can enter stream channels and lakes (<http://www.epa.gov/owow/nps>).

Further, overgrazing in the past by livestock on arid rangelands has been responsible for damage to streams in the western United States.

Grazing does not occur along the Colorado River mainstem; however, open rangeland (grazing) occurs across the watershed.

## **Forestry**

Nationally, timber harvesting and forest road activities are potential sources of sediment loading to surface water. The most detrimental effects of harvesting are related to the access and movement of vehicles and machinery (forest roads), and the dragging and loading of trees or logs. Silviculture effects include soil disturbance, soil compaction, and direct disturbance of stream channels (<http://www.epa.gov/owow/nps>).

Silviculture occurs in a relatively small portion of the Colorado River Watershed, primarily in the Kaibab National Forest. Therefore, forestry practices are probably not a significant source of sediment in the Colorado River.

## **Wildland Fires**

Wildland fire is a natural process in a forest ecosystem; however, suppression of fires and improper forest management practices can create an accumulation of fuels, such as brush and vegetative litter, on the forest floor. The additional fuel can result in hotter fires, extensive burn areas and severe damage to forest soils. (<http://www.epa.gov/owow/nps>).

The deposition of burned debris and sediment into streams and lakes during the fire can have immediate and acute effects on water quality and aquatic life. However, as U.S. Geological Survey (USGS) research has shown, the loss of ground-surface cover, such as needles and small branches, and the chemical transformation of burned soils after a fire can have long-lasting effects on the watershed as well. Watersheds become more susceptible to erosion and excess sediment from rainstorms after the burn and before the soils are stabilized.

### **Off-Highway Vehicles**

The use of off-highway vehicles, especially in sensitive areas, can increase erosion and create long-term environmental damage. This is particularly a concern within the riparian area (the channel and vegetated border along the stream) which acts as a natural filter for sediments being transported during rain events. The extent of use and damage caused by off-highway vehicles has not been documented in this watershed; however, the potential for damage is large due to erodible soils and various recreational opportunities along the Colorado River corridor.

## ***Water Quality Impacts***

**Impacts on Aquatic Life** - Excessive amounts of sediment can have the following adverse effects on aquatic life:

- Kill fish or reduce their growth rate and resistance to disease primarily by clogging or abrading gill membranes
- Prevent the successful development of fish eggs and larvae by covering spawning areas
- Modify the natural movements and migrations of fish
- Reduce the abundance of food available to fish and fish larva
- Impair the ability of sight feeding fish to locate their prey
- Reduce the amount of light available to aquatic plants, thus reducing photosynthesis and primary production in surface water and shifting algal composition from green algae to the more toxic blue-green algae
- Degrade or eliminate habitat through sedimentation and filling in of pool habitat
- Introduce toxic pollutants that can be attached to soil particles (e.g., metals, pesticides)

Some suspended sediment is natural in the Colorado River due to the sandstone formations in the Grand Canyon area. Native fish, such as the humpback chub (a federally listed endangered species) are adapted to these high levels of particulates; however, sport fish such as rainbow trout that hunt by sight, are negatively impacted by suspended sediments.

**Impacts to Recreation** - In addition to the fact that recreation may be a cause of sediment pollution, suspended sediment can interfere with recreational use and aesthetic enjoyment of surface water. Turbid waters can be dangerous to swimmers and boaters because of unseen submerged hazards. The less turbid the water, the more desirable it becomes for swimming and other water contact sports. Thus, increased suspended sediment may have potential impacts to the economy where water recreation provides a source of revenue for a community or city.

Sediment accumulation will also reduce the capacity of a reservoir and may impact navigation in channels. Dredging to remove built up sediments is costly. It is best to prevent sediment loads from entering reservoirs or channels rather than pay for removing them later.

**Impacts to Agriculture** - Agriculture can be both the cause and victim of suspended sediments in surface water. EPA's suspended sediment criteria document identifies the following negative effects of suspended solids on agricultural irrigation use:

- Formation of crusts on top of the soil that can inhibit water infiltration and plant emergence
- Decrease in soil aeration
- Formation of films on plant leaves which blocks sunlight and impedes photosynthesis, and which may reduce the marketability of some leafy crops
- Reduction in reservoir capacity and negative effects on delivery canals and other distribution equipment

**Impacts to Drinking Water** - Drinking water is filtered by public water systems, but high levels of suspended solids that may occur during flood events can overload and disrupt the filtration and treatment process. Accelerated sedimentation can also reduce the capacity of reservoirs used for drinking water supplies.

**Impacts Related to Dams** - Dams along the Colorado River must also be considered when discussing sedimentation. As the water slows its movement through a reservoir, the water loses its energy and drops its sediment load. As discussed above, this reduces the capacity of a reservoir to support recreation and drinking water storage. The more sedimentation coming into the reservoir, the faster the sediments accumulate.

The discharges from the dams along the Colorado River are both colder and clearer than the water entering the reservoirs. The water is colder because the water is taken from the deeper part of the reservoir, and clearer because sediment is retained behind the dam. The clearer water has more energy to scour the streambed downstream of the dam. These changes have significantly altered aquatic habitats.

For example, Glen Canyon Dam traps about 66 million tons of sediment per year that once flowed through the Grand Canyon. When the dam was built, the release of clear water into a canyon that once carried extremely high sediment loads resulted in substantial environmental change. Intermittent high flows and a tremendous supply of sediment historically resulted in sand beaches throughout the canyon that were used for recreation and wildlife habitat. On the other hand, sediment retention within Lake Powell prolongs the life of Lake Mead and other lakes formed by the series of dams along the river.

Streamside and channel sedimentary deposits are critical. Too much sediment causes channels to aggrade, causing flooding problems. Too little sediment load can result in habitat degradation and decrease in recreational use. Scientists have been trying to determine what would be the ideal dam release flows from Lake Powell -- what level of flow and how often the flow is needed to build beaches and to maintain habitat. Research to date indicates that beach-building flow may benefit some resources while simultaneously degrading others. Some beaches would be enlarged, others would shrink. (Collier *et al*, 1996).



## **Current Mitigation Efforts**

**Sediment Loading Studies Scheduled** - Three reaches are included on the 2004 303(d) List of Impaired Waters due to suspended sediment concentration (SSC) and are scheduled for development of a Total Maximum Daily Load study to determine sources of suspended sediment and load reductions needed to meet SSC standards.

- The Colorado River, from Parashant Canyon to Diamond Creek
- Paria River, from Utah border to the Colorado River
- Virgin River, from Beaver Dam Wash to Big Bend Wash

It is likely that the TMDL process will be used to establish site-specific standards due to natural conditions, as sandstone formations in these areas contribute significant suspended solids loadings. The loading analyses would then address any potential added contributions from human activities.

**Turbidity Loading Studies in the Little Colorado River Watershed** - ADEQ has completed two suspended sediment loading studies (TMDLs) in the Little Colorado River Watershed due to turbidity impairment – the Little Colorado River near Nutrioso Creek, and Nutrioso Creek. The Little Colorado River is a major tributary to the Colorado River. Both studies provided a list of best management practices that need to be implemented to reduce sediment loading and attain water quality standards.

**New Construction Permits** - A Stormwater Pollution Prevention Plan (SWPPP) must be developed for any construction that disturbs one acre or more. This plan is required under the Arizona Pollution Discharge Elimination System (AZPDES) Construction General Permit Program (Arizona Administrative Code R18-9-A902), administered by ADEQ. The plan must address and mitigate potential erosion and sediment transport that could occur during construction activities. More information concerning this permit can be found at ADEQ's Web site: <http://www.azdeq.gov/envIRON/water/permits/stormwater.html>.

AZPDES is an Arizona program delegated to Arizona by the U.S. EPA under the Clean Water Act. On August 22, 2005, the 9th Circuit Court of Appeals issued a decision in the case of *Defender's of Wildlife v. U.S. Environmental Protection Agency* ruling that EPA's delegation to Arizona violated the Endangered Species Act. That decision is not in effect unless and until the 9th Circuit issues an order and ADEQ continues to administer the program. Arizona and the EPA have petitioned the 9th Circuit to rehear the case.

**Best Management Practices** - The U.S. Natural Resources Conservation Service (NRCS) has taken the lead in developing effective technologies to prevent soil loss due to land uses such as: animal feeding operations, forestry, crop irrigation and cattle grazing. Information concerning recommended practices and funding opportunities to demonstrate improved technologies can be obtained through their Web site at <http://www.az.nrcs.usda.gov>.

**Glen Canyon Dam Release Studies** - To address concerns about beach erosion and native fish habitat, Congress passed the Grand Canyon Protection Act in 1992 to protect and restore natural and cultural resources and visitor use in the Grand Canyon National Park and Glen Canyon National Recreation Area. To that end, an experimental flood was released from the Glen Canyon Dam in 1996 in hopes of re-suspending sediment that had settled to the stream bed to reform beach areas.

According to USGS ([http://geology.usgs.gov/connections/bia/lis-grand\\_canyon.htm](http://geology.usgs.gov/connections/bia/lis-grand_canyon.htm)), the hypothesis was that sediment supplied by tributaries accumulates in the stream channel during normal dam operations and can be re-suspended at any time by flood flows. However, results of the experimental flood showed that tributary sand imports are carried downstream rapidly and deposited in Lake Mead and do not remain available for re-suspension at a later time. The flood was not successful in rebuilding beaches.

After studying the 1996 flood, scientists hypothesized that the flood must occur soon after tributaries have deposited a large load of sediment in order to be successful. In the fall of 2004, river managers determined that sufficient sediment had been recently deposited by tributaries to release another flood flow. Observations made after this flood confirmed that some beaches had been restored along the river. The longer-term results of the flood are still being studied.



### ***Recommended Solutions for Implementation and Funding***

The control of anthropogenic sediment can be accomplished at one of three levels:

- Prevention – not causing erosion or preventing the sediment from leaving the site
- Interdiction – capturing and retaining sediment between the site of origin and the surface water. Two principal means:
  - Buffer strips of vegetation to filter and retain sediment, generally as part of a riparian area
  - Sediment traps or sediment basins
- Restoration – removing sediment from the surface water:
  - Dredging
  - Dam releases to transport sediments downstream or establish desired beaches

The cost to society increases when intervention occurs further from the source; therefore, resources are best spent to prevent erosion. The most costly corrections occur when we attempt to restore an area.

- **Promote the use of best management practices to address erosion and sedimentation primarily through education and outreach.**
  - A. Develop watershed-based plans to identify and implement sediment load reducing practices.
  - B. Develop and make available a list of best management practices for sediment control that evaluates their costs and effectiveness.
  - C. Develop additional outreach for ADEQ's General Construction Permit.
  - D. Encourage best management practices to reduce urban and construction runoff.

- **Educate and potentially regulate off-highway vehicles.**

Local governments and land management agencies should be encouraged to develop and enforce restrictions of off-highway vehicles in sensitive areas such as within a riparian area, including the stream channel. As this is a popular form of recreation, education and outreach materials should be developed so that the public is aware of the need to protect riparian areas and how off-highway vehicle drivers can be involved in this protection effort.

- **Advocate projects and funding that properly manage forests and other public lands to minimize wildfire impacts.**

The U.S. Forest Service and other land management agencies should be supported in their efforts to reduce the potential for uncontrolled wildfires. Encourage funding projects that reseed and replant vegetation after a fire to reduce destructive runoff of soil during rain events, especially in vulnerable areas such as along steep slopes.

- **Continue revision of water quality standards related to erosion and sedimentation based on sound science.**

**A. Several revisions to Arizona's narrative and numeric water quality standards are being proposed in the current Triennial Review of standards.** ADEQ needs to continue the development of physical integrity criteria for surface waters that are appropriate for the varying ecoregions in this state, including those represented in the Colorado River Watershed.

**B. Develop site-specific standards and suspended sediment concentration loading analyses in the Colorado River and its tributaries.** These TMDLs are scheduled to be initiated in 2010, but before loadings can be calculated ADEQ must:

- Estimated natural background loading attributed to sandstone formations throughout the Grand Canyon, including natural background contributions from its tributaries and
- If natural background loading alone would exceed the SSC standard, establish a site-specific suspended sediment concentration standard. This standard would need to balance aquatic life protection and downstream sedimentation with other concerns, such as the desire for sandy recreational beaches.

**C. Support and help fund research to identify sediment tolerant macroinvertebrates.**

To properly interpret biocriteria assessments based on macroinvertebrate communities, Arizona should support research being conducted by the Western Bioassessment Center to identify sediment tolerant macroinvertebrates. If sediment tolerant macroinvertebrates are present and others are not, this would provide supporting evidence that sediment is the cause of aquatic impairment.

- **Continue evaluation of the Glen Canyon Dam operations impacts to sedimentation.**

Encourage continuation of federal investigations to determine the sediment loadings and dam discharges that best supports recreational opportunities and habitat downstream of the dam. Such scientific investigations are necessary to properly establish site-specific standards for suspended sediment concentration in the Colorado River below Glen Canyon Dam.

## ***Action Plan for Implementation and Funding***

The following action plan is based on the recommendations identified above:

- Local governments, land and resource management agencies, and ADEQ should collaborate on efforts to implement erosion/sedimentation control best management practices, primarily through the development of education and outreach materials.
- ADEQ should develop educational materials that compare the unit cost, applicability, limitations and effectiveness of best management practices that control erosion and reduce sedimentation.
- ADEQ should provide more outreach for development of Stormwater Pollution Prevention Plans to control erosion at construction sites.
- The State should support the U.S. Forest Service and other land management agencies in implementing procedures that reduce the potential for uncontrolled wildland fires. Support funding projects to reseed and replant after destructive wildland fires occur, especially in vulnerable areas.
- Arizona should support science-based development and revisions of sedimentation-related narrative and numeric water quality standards through ADEQ's Clean Water Act Triennial Review process.
- ADEQ should re-evaluate its suspended sediment concentration standard in the Grand Canyon area where sandstone formations and natural erosion are probably contributing sediment loads above existing water quality standards.
- ADEQ should work with stakeholders to develop site-specific standards for suspended sediment that account for natural background conditions. These site-specific standards are needed before the requirement TMDL loading analyses can be completed.
- Arizona should support and help fund research into sediment tolerant macroinvertebrates, so that biocriteria can be a more effective tool to assess water quality impairment.



## Conclusions

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## Conclusions

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Governor Napolitano and other elected officials, community leaders, local stakeholders and concerned citizens, throughout Arizona are encouraged to consider the recommendations provided herein for the protection and improvement of Colorado River's water quality. The Colorado River provides drinking water to more than 25 million people and irrigation water to support two million acres of agricultural production. The recommendations proposed in this report, if implemented, can reduce the threat posed to the Colorado River by pollutants such as nutrients, metals, endocrine disrupting compounds, perchlorate, bacteria, salinity and sediment.

Recommendations range from addressing the pollutants through regulatory and structural change to staying the course by continuing to provide funding and support for essential programs. Many of the recommendations deal with improving information dissemination, existing regulatory processes and structures. Public education and outreach programs such as public service announcements, presentations to service organizations, councils, and schools need improvements, funding and staff. For example, providing information regarding proper waste disposal for recreational users along the river may decrease the amount of bacteria threatening the Colorado River. Controlling runoff or nonpoint source pollution by planting vegetation, buffer strips and other best management practices can control pollutants such as sediment, nutrients, metals, bacteria and salinity. Through the design of regulatory and structural controls and pollution prevention control strategies, pollutants may be reduced.

While many of the recommendations contained in this report deal with on-the-ground implementation, there are some recommendations for additional monitoring and characterization to determine the occurrence or potential impacts to the River. Before specific recommendations can be developed for metals and endocrine disrupting compounds, the Alliance believes that additional information is needed for characterization and sampling to determine the concentration in the River and potential sources. In addition, studies on aging and inadequate wastewater systems should be conducted to identify wastewater needs and prioritize locations for implementation to control bacteria and nutrients.

The Alliance also concluded in some cases that current efforts by private industry, federal and state entities should continue to be supported. For instance, continued — and increased — funding and support is needed for governmental agencies to provide proactive measures and prompt response to control and remediate existing pollution.

In many cases (five of the seven pollutant chapters), funding is an essential element to implement the recommendations. For example, capital investment recommendations and facility maintenance require funding. Funding must be identified, directed and secured for many of the recommendations identified in the report. Potential funding sources include but are not limited to: U.S. EPA, Center for Disease Control, Metropolitan Water District, Southern Nevada Water Authority, municipal providers, U.S. Fish and Wildlife Service, Wildlife Conservation Fund, Heritage Grant Funds, Legacy Funds, State Lake Improvement Fund, ADEQ's Water Quality Improvement Grant Program, Water Infrastructure Finance Authority, U.S. Department of Agriculture's Environmental Quality Incentives Program, Rural Development Assistance, ADWR's Water Protection Fund. Refer to the individual pollutant chapters for funding sources related to controlling each of the specific water quality issues identified by the Alliance. A variety of potential funding sources should be sought to implement the recommendations of the Alliance.

Focusing on a sustainable future for the citizens of Arizona with assured Colorado River water quality requires a regional approach. As Governor Janet Napolitano stated in her Clean Colorado River Alliance invitation to serve, the water quality issues identified in this report “are, in fact, regional issues and cannot be tackled on solely a state level.” Without a regional approach, the Colorado River’s water quality will remain threatened.

These recommendations are tools that should be used to maintain adequate water quality in the Colorado River and mitigate impacts in water quality. The Clean Colorado River Alliance recommends that implementation of the recommendations in this report begin in 2006. Funding should be sought for priority recommendations. This report is the first step to a much larger, regional approach to address water quality issues in Colorado River Watershed. To improve Colorado River’s water quality for all 25 million people who depend on the River for everyday use, more watershed-scale collaboration on monitoring and research must be initiated. Addressing water quality issues is essential in the protection and improvement of the Colorado River, the lifeblood of the American West.





## Appendix 1

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STATE OF ARIZONA

JANET NAPOLITANO  
GOVERNOR

OFFICE OF THE GOVERNOR  
1700 WEST WASHINGTON STREET, PHOENIX, AZ 85007

MAIN PHONE: 602-542-4331  
FACSIMILE: 602-542-7601

February 8, 2005

Greetings:

The Colorado River serves as the lifeblood of the American West providing drinking water to more than 25 million people and irrigation water to support 2 million acres of agricultural production. For years the focus of the Colorado has been on water quantity and indeed, I will continue to fight to secure our share of this critical resource. However, we can no longer focus on water quantity alone; we must address water quality as well if we are to truly meet the needs of the state.

There are several major issues currently threatening the quality of water in the Colorado River. Unfortunately, the problems tend to accumulate with movement downstream, and Arizona is the last State to divert flows from the Colorado before it crosses into Mexico. While many of the problems manifest themselves most severely in Arizona due to geographic location, the problems are, in fact, regional issues and cannot be tackled on solely a state level.

Effectively cleaning up the Colorado River will require a regional approach involving federal, state, tribal and local governments as well as other key stakeholders including agricultural, municipal, business and conservation sectors. Therefore, I have decided to name a stakeholders group, the Clean Colorado River Alliance (CCRA), to develop recommendations to address existing water quality problems.

I ask you to serve on this important stakeholders group and assist me in working with our fellow states towards solutions. A full list of people being asked to serve on the CCRA is attached.

I hope you will be able to personally participate on the CCRA, and I look forward to your advice on the Colorado River water pollution issues.

Yours very truly,

Janet Napolitano  
Governor



## Appendix 2

Draft Pollutant List			
Pollutant	Discussed at April Meeting	CCRA Input	Basin States Input
Discussed at April Meeting			
Uranium	X	X	
Nitrogen/Nitrates	X	X	
Perchlorate	X	X	
Chromium VI	X	X	
Salinity/Total Dissolved Solids	X	X	X
Pesticides/herbicides	X	X	
Selenium	X	X	X
Sediment/turbidity	X	X	X
Bacteria/pathogens	X	X	X
Boron	X		X
Additional Pollutants from CCRA			
Endocrine Disrupting Compounds (personal pharmaceutical products)		X	
Mercury		X	X
PAH (Benzo pyrene)		X	
MTBE (methyl-t-butyl ether)		X	
PCB (Polychlorinated bi-phenyls)		X	
Dioxin		X	
Hydrocarbons		X	
Carbon Monoxide		X	
Nutrients		X	X
Dissolved oxygen		X	X
Additional Pollutants from Basin States			
Phosphorus			X
pH			X
Aluminum			X
Ammonia			X
Chlorine			X
Temperature			X
Cadmium			X
Copper			X
Zinc			X



## Appendix 3

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### **Pollutant Workgroups**

#### **Chapter 2 - Nutrients**

##### **Workgroup Participants**

Dean Barlow, Lake Havasu Park Board  
Kathy Carroll, City of Yuma  
Val Danos, Arizona Municipal Water Users Association  
Bob Ericson, Water Conservation District Member  
Gene Fisher, LaPaz County Supervisor  
Maureen Rose George, Law Offices of Maureen Rose George  
Roger Gingrich, City of Yuma  
Jack Hakim, Bullhead City Councilman  
Patty Mead, Mohave County Health and Social Services  
Rachel Patterson, Mohave County Health and Social Services  
Robert Shuler, Ryley, Carlock & Applewhite  
John Sullivan, Salt River Project  
Mayor Robert Whelan, Lake Havasu City  
Doyle Wilson, Lake Havasu City

#### **Chapter 3 - Metals**

##### **Workgroup Participants**

Peter Culp, Sonoran Institute  
Susan Fitch, Arizona Department of Water Resources  
Kirk Koch, Bureau of Land Management  
Linda Taunt, Arizona Department of Water Resources  
Bill Werner, Arizona Department of Water Resources  
Doyle Wilson, Lake Havasu City

#### **Chapter 4 - Endocrine Disrupting Compounds**

##### **Workgroup Participants**

Peter Culp, Sonoran Institute  
Marie Light, City of Tucson  
Hsin-I Lin, Arizona Department of Health Services  
Dave Weedman, Arizona Game and Fish Department  
Doyle Wilson, Lake Havasu City

## **Chapter 5 - Perchlorate**

### **Workgroup Participants**

Aubrey Baure, US Air Force / Department of Defense REC 9  
Randall Gerard, EOP Group  
Hsin-I Lin, Arizona Department of Health Services  
Doug Mellon, Doug Mellon Farms  
Mayor Larry Nelson, City of Yuma  
Gary Pasquinelli, Pasquinelli Produce  
Robert Shuler, Ryley, Carlock & Applewhite  
Sid Wilson, Central Arizona Project

## **Chapter 6 - Bacteria**

### **Workgroup Participants**

Dean Barlow, Lake Havasu Park Board  
Maureen Rose George, Law Offices of Maureen Rose George  
Kirk Koch, Bureau of Land Management  
Patty Mead, Mohave County Health and Social Services  
Rachel Patterson, Mohave County Health and Social Services

## **Chapter 7 - Salinity/Total Dissolved Solids**

### **Workgroup Participants**

Joan Card, Arizona Department of Environmental Quality  
Val Danos, Arizona Municipal Water Users Association  
Peter Culp, Sonoran Institute  
Marie Light, City of Tucson  
Frank Putman, Arizona Department of Water Resources  
Sid Wilson, Central Arizona Project

## **Chapter 8 - Sediment and Suspended Solids**

### **Workgroup Participants**

Joan Card, Arizona Department of Environmental Quality  
Diana Marsh, Arizona Department of Environmental Quality  
Tom Griffin, Griffin and Associates  
Nick Ramsey, Grand Canyon Trust



## Appendix 4

### Observed Flow-Weighted Average Salinity at the Numeric Criteria Stations (Total Dissolved Solids in mg/L)<sup>a</sup>

Calendar Year Below (Numeric Criteria)	Hoover Dam (723 mg/L)	Below Parker Dam (747 mg/L)	At Imperial Dam (879 mg/L)
1970	743	760	896
1971	748	758	892
1972	724	734	861
1973	675	709	843
1974	681	702	834
1975	680	702	829
1976	674	690	822
1977	665	687	819
1978	678	688	812
1979	688	701	802
1980	691	712	760
1981	681	716	821
1982	679	713	827
1983	659	678	727
1984	598	611	675
1985	556	561	615
1986	517	535	577
1987	519	538	612
1988	529	540	648
1989	564	559	683
1990	587	600	702
1991	629	624	749
1992	657	651	767
1993	665	631	785
1994	667	673	796
1995	654	671	803
1996	618	648	768
1997	585	612	710
1998	559	559	655
1999	549	550	670
2000	539	549	661
2001	550	549	680
2002	564	569	691
2003	583	589	697
2004 provisional	655	649	737

\* Determined by the U.S. Geological Survey (USGS) from data collected by the U.S. Bureau of Reclamation and USGS and published in Quality of Water, Colorado River Basin, Progress Report No. 22, 2005.

The flow-weighted average annual salinity is the concentration determined from dividing the annual total salt load passing a measuring station by the total annual volume of water passing the same point during a calendar year. The flow-weighted average annual salinity is calculated by first multiplying the daily concentration values by the daily flow rates. These values are then summed over a calendar year and divided by the sum of the daily flow rate (Forum, 2002).



### **POLICY FOR IMPLEMENTATION OF COLORADO RIVER SALINITY STANDARDS THROUGH THE NPDES PERMIT PROGRAM**

**Adopted by  
The Colorado River Basin Salinity Control Forum**

**February 28, 1977  
Revised October 30, 2002**

In November 1976, the United States Environmental Protection Agency Regional Administrators notified each of the seven Colorado River Basin states of the approval of the water quality standards for salinity for the Colorado River System as contained in the document entitled "Proposed Water Quality Standards for Salinity Including Numeric Criteria and Plan of Implementation for Salinity Control, Colorado River System, June 1975, and the supplement dated August 25, 1975. The salinity standards including numeric criteria and a plan of implementation provide for a flow weighted average annual numeric criteria for three stations in the lower main stem of the Colorado River: below Hoover Dam, below Parker Dam, and at Imperial Dam.

In 1977, the states of the Colorado River Basin adopted the "Policy for Implementation of Colorado River Salinity Standards through the NPDES Permit Program." The plan of implementation is comprised of a number of Federal and non Federal projects and measures to maintain the flow weighted average annual salinity in the Lower Colorado River at or below numeric criteria at the three stations as the Upper and Lower Basin states continue to develop their compact apportioned waters. One of the components of the Plan consists of the placing of effluent limitations, through the National Pollutant Discharge Elimination System (NPDES) permit program, on industrial and municipal discharges.

#### **NPDES Policy for Municipal and Industrial Discharges of Salinity in the Colorado River**

The purpose of this policy is to provide more detailed guidance in the application of salinity standards developed pursuant to Section 303 and through the NPDES permitting authority in the regulation of municipal and industrial sources. (See Section 402 of the Federal Water Pollution Control Act.) The objective of the policy, as provided in Sections I.A. and I.B., is to achieve "no salt return" whenever practicable for industrial discharges and an incremental increase in salinity over the supply water for municipal discharges. This policy is applicable to discharges that would have an impact, either direct or indirect on the lower main stem of the Colorado River System. The lower main stem is defined as that portion of the River from Hoover Dam to Imperial Dam.

#### **NPDES Policies Separately Adopted By The Forum**

The Forum developed a separate and specific policy for the use of brackish and/or saline waters for industrial purposes on September 11, 1980. The Forum addressed the issue of intercepted ground water and adopted a specific policy dealing with that type of discharge

on October 20, 1982. On October 28, 1988, the Forum adopted a specific policy addressing the water use and discharge associated with fish hatcheries. Each of these separately adopted policies is attached hereto.

### **NPDES Policies For Specified Industrial Discharges**

On October 30, 2002, the Forum amended this policy for implementation of Colorado River salinity standards through the NPDES permit program in order to address the following three additional types of industrial discharges: (1) water that has been used for once through non-contact cooling water purposes; (2) new industrial sources that have operations and associated discharges at multiple locations; and (3) "fresh water industrial discharges" where the discharged water does not cause or contribute to exceedances of the salinity standards for the Colorado River System. This policy was also amended to encourage new industrial sources to conduct or finance one or more salinity offset projects in cases where the permittee has demonstrated that it is not practicable to prevent the discharge of all salt from proposed new construction.

### **Discharges Of Once Through Noncontact Cooling Water**

Section I.C. of this policy has been added to address discharges of water that has been used for once through noncontact cooling water purposes. The policy for such discharges shall be to permit these uses based upon a finding that the returned water does not contribute to the loading or the concentration of salts in the waters of the receiving stream beyond a de minimis amount. A de minimis amount is considered, for purposes of this policy, as an average annual increase of not more than 25 milligrams per liter (mg/L) in total dissolved solids measured at the discharge point or outfall prior to any mixing with the receiving stream in comparison to the total dissolved solids concentration measured at the intake monitoring point of the cooling process or facility. This policy is not intended to supersede any other water quality standard that applies to the receiving stream, including but not limited to narrative standards promulgated to prohibit impairment of designated uses of the stream. It is the intent of the Forum to permit the return of once through noncontact cooling water only to the same stream from which the water was diverted. Noncontact cooling water is distinguished from blowdown water, and this policy specifically excludes blowdown or any commingling of once through noncontact cooling water with another waste stream prior to discharge to the receiving stream. Sections I.A. and I.B. of this policy govern discharges of blowdown or commingled water.

### **New Industrial Sources with Operations and Discharges at Multiple Locations under Common or Affiliated Ownership or Management**

Recently there has been a proliferation of new industrial sources that have operations and associated discharges at multiple locations. An example is the recent growth in the development of energy fuel and mineral resources that has occurred in the Upper Colorado River Basin. This type of industrial development may involve the drilling of relatively closely spaced wells into one or more geological formations for the purpose of extracting oil, gas or minerals in solution. Large scale ground water remediation efforts involving multiple pump and treat systems operating for longer than one year may share similar characteristics. With such energy and mineral development and ground water remediation efforts there is the possibility of a single major industrial operation being comprised of numerous individual point source discharges under common or affiliated ownership or management that produce significant quantities of

water as a waste product or byproduct over a long period. Given the large areal scope of these types of major industrial sources and the often elevated concentrations of salinity in their produced water, the total amount of salt loading that they could generate may be very large in comparison to the Forum's past and present salt removal projects. Relatively small quantities of this produced water could generate one ton per day in discharges to surface waters. Since salinity is a conservative water quality constituent, such discharges of produced water, if uncontrolled, could have an adverse effect on achieving the adopted numeric salinity standards for the Colorado River System.

These kinds of major industrial sources strain the conventional interpretation of the industrial source waiver for new construction set forth in Section I.A.1.a. of this policy, which authorizes a discharge of salinity from a single point source of up to one ton per day in certain circumstances. The Forum adopted this provision in 1977, well before most of the new major industrial sources that have operations and discharges at multiple locations began to appear in the Colorado River Basin. A new category of industrial sources is, therefore, warranted. NPDES permit requirements for New Industrial Sources with Operations and Discharges at Multiple Locations under Common or Affiliated Ownership or Management are set forth in Section I.D. of this policy. These new requirements are intended to apply to new industrial sources with operations that commence discharging after October 30, 2002.

For purposes of interpreting this policy, "common or affiliated ownership or management" involves the authority to manage, direct, superintend, restrict, regulate, govern, administer, or oversee, or to otherwise exercise a restraining or directing influence over activities at one or more locations that result in a discharge of salinity into the Colorado River System. Common or affiliated ownership or management may be through the ownership of voting securities or may be indicated where individual sources are related through one or more joint ventures, contractual relationships, landlord/tenant or lessor/lessee arrangements. Other factors that indicate two or more discharging facilities are under common or affiliated ownership or management include: sharing corporate executive officers, pollution control equipment and responsibilities, common workforces, administrative functions, and/or payroll activities among operational facilities at different locations.

### **Fresh Water Industrial Discharges**

Sections I.A. and I.B. of this policy have been amended to allow the permitting authority to authorize "fresh water industrial discharges" where the discharged water does not cause or contribute to exceedances of the adopted numeric salinity standards for the Colorado River System. Different end of pipe concentrations of salinity as shown in Table 1 of the policy, are appropriate for discharges to tributaries depending upon their location within the Basin. The concept of "benchmark concentrations" has been developed in order to address this need for different end of pipe concentrations. These benchmark concentrations are not to be interpreted as water quality standards. Rather, they are intended to serve solely for the establishment of effluent limits for implementing the waiver for "fresh water discharges." The allowance for freshwater discharges is intended to preserve flows from discharges in the Basin, which do not cause significant degradation of existing ambient quality with respect to salinity. Operations or individual discharges that qualify for the freshwater waiver shall not be subject to any further limitation on salt loading under this policy.

## **Salinity Offset Projects**

This policy has been amended to allow the permitting authority to authorize industrial sources of salinity to conduct or finance one or more salinity offset projects when the permittee has determined that it is not practicable: (i) to prevent the discharge of all salt from proposed new construction; (ii) to reduce the salt loading to the Colorado River to less than one ton per day or 366 tons per year; or (iii) the proposed discharge is of insufficient quality in terms of TDS concentrations that it could be considered "fresh water" as defined below. Presently, the permitting authority can consider the costs and availability of implementing off site salinity control measures to mitigate the adverse impacts of the permitted salt load. It is not intended that the applicant be required to develop or design an off site salinity control project or establish a salt bank, but rather to assess the costs of conducting or buying into such projects where they are available. In the future the Forum or another entity may create a trading/banking institution to facilitate the implementation of a salinity offset program, basin wide. This would allow industrial sources to conduct or finance the most cost effective project available at the time an offset project is needed regardless of the project's location in the Basin.



### **NPDES PERMIT PROGRAM POLICY FOR IMPLEMENTATION OF COLORADO RIVER SALINITY STANDARDS**

#### **I. Industrial Sources**

The Salinity Standards state that "The objective for discharges shall be a no salt return policy whenever practicable." This is the policy that shall be followed in issuing NPDES discharge permits for all new industrial sources, and upon the reissuance of permits for all existing industrial sources, except as provided herein. The following addresses those cases where "no discharge of salt" may be deemed not to be practicable.

#### **A. New Construction**

1. "New construction" is defined as any facility from which a discharge may occur, the construction of which is commenced after October 18, 1975. (Date of submittal of water quality standards as required by 40 CFR 120, December 11, 1974.) Appendix A provides guidance on new construction determination. "A new industrial source with operations and discharging facilities at multiple locations under common or affiliated ownership or management" shall be defined for purposes of NPDES permitting, as an industrial source that commenced construction on a pilot, development or production scale on or after October 30, 2002.

- a. The permitting authority may permit the discharge of salt upon a satisfactory demonstration by the permittee that:
  - i. It is not practicable to prevent the discharge of all salt from the new construction or,
  - ii. In cases where the salt loading to the Colorado River from the new construction is less than one ton per day or 366 tons per year, or
  - iii. The proposed discharge from the new construction is of sufficient quality in terms of TDS concentrations that it can be considered "fresh water" that would have no adverse effect on achieving the adopted numeric standards for the Colorado River System. The permitting authority may consider a discharge to be fresh water if the maximum TDS concentration is: (i) 500 mg/L for discharges into the Colorado River and its tributaries upstream of Lees Ferry, Arizona; or, (ii) 90% of the applicable in stream salinity standard at the appropriate benchmark monitoring station for discharges into the Colorado River downstream of Lees Ferry as shown in Table 1, below:

**Table 1**

<b>Benchmark Monitoring Station</b>	<b>Applicable Criteria</b>	<b>Freshwater Discharge (mg/L)</b>
Colorado River at Lees Ferry, Arizona	N/A	500
Colorado River below Hoover Dam	723	650
Colorado River below Parker Dam	747	675
Colorado River at Imperial Dam	879	790

- b. Unless exempted under Sections I.A.1.a.ii. or iii., above, the demonstration by the applicant must include information on the following factors relating to the potential discharge:
- (i) Description of the proposed new construction.
  - (ii) Description of the quantity and salinity of the water supply.
  - (iii) Description of water rights, including diversions and consumptive use quantities.
  - (iv) Alternative plans that could reduce or eliminate salt discharge. Alternative plans shall include:
    - (A) Description of alternative water supplies, including provisions for water reuse, if any;
    - (B) Description of quantity and quality of proposed discharge;
    - (C) Description of how salts removed from discharges shall be disposed of to prevent such salts from entering surface waters or groundwater aquifers;
    - (D) Costs of alternative plans in dollars per ton of salt removed; and
    - (E) Unless the permitting authority has previously determined through prior permitting or permit renewal actions that it is not practicable to prevent the discharge of all salt from the new construction in accordance with Section I.A.1.a.i., the applicant must include information on project options that would offset all or part of the salt loading to the Colorado River associated with the proposed discharge or that would contribute to state or interstate salinity control projects or salt banking programs.
  - (v) A statement as to the one plan among the alternatives for reduction of salt discharge that is recommended by the applicant and also information as to which of the other evaluated alternatives are economically infeasible.

- (vi) Such other information pertinent to demonstration of non practicability as the permitting authority may deem necessary.
- c. In determining what permit conditions shall be required under I.A.1.a.i., above, the permit issuing authority shall consider, but not be limited to the following:
  - (i) The practicability of achieving no discharge of salt from the new construction.
  - (ii) Where "no discharge" is determined not to be practicable:
    - (A) The impact of the total proposed salt discharge of each alternative on the lower main stem in terms of both tons per year and concentration.
    - (B) Costs per ton of salt removed from the discharge for each plan alternative.
    - (C) Capability of minimizing salinity discharge.
    - (D) If applicable under I.A.1.b.(iv)(E), costs and practicability of offsetting all or part of the salt load by the implementation of salt removal or salinity control projects elsewhere in the Colorado River Basin. The permittee shall evaluate the practicability of offsetting all or part of the salt load by comparing such factors as the cost per ton of salt removal for projects undertaken by the Colorado River Basin Salinity Control Forum and the costs in damages associated with increases in salinity concentration against the permittee's cost in conducting or buying into such projects where they are available.
  - iii. With regard to subparagraphs, (b) and (c) above, the permit issuing authority shall consider the compatibility of state water laws with either the complete elimination of a salt discharge or any plan for minimizing a salt discharge.
- B. Existing Facilities or any discharging facility, the construction of which was commenced before October 18, 1975
  - 1. The permitting authority may permit the discharge of salt upon a satisfactory demonstration by the permittee that it is not practicable to prevent the discharge of all salt from an existing facility.
  - 2. The demonstration by the applicant must include, in addition to that required under Section I.A.1.b the following factors relating to the potential discharge:
    - a. Existing tonnage of salt discharged and volume of effluent.
    - b. Cost of modifying existing industrial plant to provide for no salt discharge.
    - c. Cost of salt minimization.
  - 3. In determining what permit conditions shall be required, the permit issuing authority shall consider the items presented under I.A.1.c.(ii), and in addition; the annual costs of plant modification in terms of dollars per ton of salt removed for:

- a. No salt return.
  - b. Minimizing salt return.
- 4. The no salt discharge requirement may be waived in those cases where:
  - a. The discharge of salt is less than one ton per day or 366 tons per year; or
  - b. The permitting authority determines that a discharge qualifies for a "fresh water waiver" irrespective of the total daily or annual salt load. The maximum TDS concentration considered to be fresh water is 500 mg/L for discharges into the Colorado River and its tributaries upstream of Lees Ferry, Arizona. For discharges into the Colorado River downstream of Lees Ferry the maximum TDS concentration considered to be afresh water shall be 90% of the applicable in stream standard at the appropriate benchmark monitoring station shown in Table 1, above.

#### C. Discharge of Once Through Noncontact Cooling Water

- 1. Definitions:
  - a. The terms "noncontact cooling water" and "blowdown" are defined as per 40CFR 401.11 (m) and (n).
  - b. "Noncontact cooling water" means water used for cooling that does not come into direct contact with any raw material, intermediate product, waste product or finished product.
  - c. "Blowdown" means the minimum discharge of recirculating water for the purpose of discharging materials contained in the water, the further buildup of which would cause concentration in amounts exceeding limits established by best engineering practice.
  - d. "Salinity" shall mean total dissolved solids as the sum of constituents.
- 2. Permits shall be authorized for discharges of water that has been used for once through noncontact cooling purposes based upon a finding that the returned water does not contribute to the loading of salts or the concentration of salts in the waters of the receiving stream in excess of a de minimis amount.
- 3. This policy shall not supplant nor supersede any other water quality standard of the receiving stream adopted pursuant to the Federal Clean Water Act, including but not limited to impairment of designated uses of the stream as established by the governing water quality authority having jurisdiction over the waters of the receiving stream.
- 4. Noncontact cooling water shall be distinguished from blowdown, and Section 1.C. of this policy specifically excludes blowdown or any commingling of once through non-contact cooling water with another waste stream prior to discharge to the receiving

stream. Sections I.A. and I.B of this policy shall in all cases govern discharge of blow-down or commingled water.

5. Once through noncontact cooling water shall be permitted to return only to the same stream from which the water was diverted.
6. Because the increase in temperature of the cooling water will result in some evaporation, a de minimis increase in the concentration of dissolved salts in the receiving water may occur. An annual average increase in total dissolved solids of not more than 25 milligrams per liter (mg/L) measured at the intake monitoring point, as defined below, of the cooling process or facility, subtracted from the effluent total dissolved solids immediately upstream of the discharge point to the receiving stream, shall be considered de minimis.
7. At the time of NPDES discharge permit issuance or reissuance, the permitting authority may permit a discharge in excess of the 25 mg/L increase based upon a satisfactory demonstration by the permittee pursuant to Section 1.A.1.a.
8. Once through demonstration data requirements:
  - a. Description of the facility and the cooling process component of the facility.
  - b. Description of the quantity, salinity concentration and salt load of intake water sources.
  - c. Description of the discharge, covering location, receiving waters, quantity of salt load and salinity concentration of both the receiving waters and the discharge.
  - d. Alternative plans for minimizing salt discharge from the facility which shall include:
    - (i) Description of alternative means to attain no discharge of salt.
    - (ii) Cost of alternative plans in dollars per ton of salt removed from discharge.
    - (iii) Such other information pertinent to demonstration of non practicability as the permitting authority may deem necessary.
9. If, in the opinion of the permitting authority, the database for the salinity characteristics of the water source and the discharge is inadequate, the permit will require that the permittee monitor the water supply and the discharge for salinity. Such monitoring program shall be completed in two years and the permittee shall then present the once through demonstration data as specified above.
10. All new and reissued NPDES permits for once through noncontact cooling water discharges shall require at a minimum semiannual monitoring of the salinity of the intake water supply and the effluent, as provided below.
  - a. The intake monitoring point shall be the point immediately before the point of use of the water.

- b. The effluent monitoring point shall be prior to the discharge point at the receiving stream or prior to commingling with another waste stream or discharge source.
- c. Discrete or composite samples may be required at the discretion of the permitting authority, depending on the relative uniformity of the salinity of the water supply.
- d. Analysis for salinity may be either total dissolved solids or electrical conductivity where a satisfactory correlation with total dissolved solids has been established. The correlation shall be based on a minimum of five different samples.

D. Discharges of Salinity from a New Industrial Source with Operations and Discharging Facilities at Multiple Locations

- 1. The objective for discharges to surface waters from a new industrial source with operations and discharging facilities at multiple locations shall be to assure that such operations will have no adverse effect on achieving the adopted numeric salinity standards for the Colorado River System.
- 2. NPDES permit requirements for a new industrial source with operations and discharging facilities at multiple locations shall be defined, for purposes of establishing effluent limitations for salinity, as a single industrial source if these facilities meet the criteria:
  - a. The discharging facilities are interrelated or integrated in any way including being engaged in a primary activity or the production of a principle product; and
  - b. The discharging facilities are located on contiguous or adjacent properties or are within a single production area e.g. geologic basin, geohydrologic basin, coal or gas field or 8 digit hydrologic unit watershed area; and
  - c. The discharging facilities are owned or operated by the same person or by persons under common or affiliated ownership or management.
- 3. The permitting authority may permit the discharge of salt from a new industrial source with operations and discharging facilities at multiple locations if one or more of the following requirements are met:
  - a. The permittee has demonstrated that it is not practicable to prevent the discharge of all salt from the industrial source. This demonstration by the applicant must include detailed information on the factors set forth in Section I.A.1.b of the Policy for implementation of Colorado River Salinity Standards through the NPDES permit program; with particular emphasis on an assessment of salinity off set options that would contribute to state or interstate salinity control projects or salt banking programs and offset all or part of the salt loading to the Colorado River associated with the proposed discharge.

- b. In determining what permit conditions shall be required under I.A.1.a.i., above, the permit issuing authority shall consider the requirement for an offset project to be feasible if the cost per ton of salt removal in the offset project options ( i.e. the permittee's cost in conducting or buying into such projects where they are available) is less than or equal to the cost per ton of salt removal for projects undertaken by the Colorado River Basin Salinity Control Forum or less than the cost per ton in damages caused by salinity that would otherwise be cumulatively discharged from the outfalls at the various locations with operations controlled by the industrial source; or
  - c. The permittee has demonstrated that one or more of the proposed discharges is of sufficient quality in terms of TDS concentrations to qualify for a "fresh water waiver" from the policy of "no salt return, whenever practical." An individual discharge that can qualify for a fresh water waiver shall be considered to have no adverse effect on achieving the adopted numeric salinity standards for the Colorado River System.
- 4. For the purpose of determining whether a freshwater waiver can be granted, the quality of water discharged from the new industrial source with operations and discharging facilities at multiple locations, determined as the flow weighted average of salinity measurements at all outfall points, must meet the applicable benchmark concentration in accordance with Section I.A.1.a.iii., as set forth above.
- 5. Very small scale pilot activities, involving 5 or fewer outfalls, that are sited in areas not previously developed or placed into production by a new industrial source operations and discharges at multiple locations under common or affiliated ownership or management, may be permitted in cases where the discharge of salt from each outfall is less than one ton per day or 366 tons per year. However, no later than the date of the first permit renewal after the pilot activities have become part of a larger industrial development or production scale effort, all discharging facilities shall be addressed for permitting purposes as a single industrial source with operations and discharges at multiple locations under common or affiliated ownership or management.
- 6. The public notice for NPDES permits authorizing discharges from operations at multiple locations with associated outfalls shall be provided promptly and in the most efficient manner to all member states in the Colorado River Basin Salinity Control Forum in relation to this policy.

## II. Municipal Discharges

The basic policy is that a reasonable increase in salinity shall be established for municipal discharges to any portion of the Colorado River stream system that has an impact on the lower main stem. The incremental increase in salinity shall be 400 mg/L or less, which is considered to be a reasonable incremental increase above the flow weighted average salinity of the intake water supply.

- F. The permitting authority may permit a discharge in excess of the 400 mg/L incremental increase at the time of issuance or reissuance of a NPDES discharge permit, upon

satisfactory demonstration by the permittee that it is not practicable to attain the 400 mg/L limit.

G. Demonstration by the applicant must include information on the following factors relating to the potential discharge:

1. Description of the municipal entity and facilities.
2. Description of the quantity and salinity of intake water sources.
3. Description of significant salt sources of the municipal wastewater collection system, and identification of entities responsible for each source, if available.
4. Description of water rights, including diversions and consumptive use quantities.
5. Description of the wastewater discharge, covering location, receiving waters, quantity, salt load, and salinity.
6. Alternative plans for minimizing salt contribution from the municipal discharge. Alternative plans should include:
  - a. Description of system salt sources and alternative means of control.
  - b. Cost of alternative plans in dollars per ton, of salt removed from discharge.
7. Such other information pertinent to demonstration of non-practicability as the permitting authority may deem necessary.

H. In determining what permit conditions shall be required, the permit issuing authority shall consider the following criteria including, but not limited to:

1. The practicability of achieving the 400 mg/L incremental increase.
2. Where the 400 mg/L incremental increase is not determined to be practicable:
  - a. The impact of the proposed salt input of each alternative on the lower main stem in terms of tons per year and concentration.
  - b. Costs per ton of salt removed from discharge of each alternative plan.
  - c. Capability of minimizing the salt discharge.

D. If, in the opinion of the permitting authority, the data base for the municipal waste discharger is inadequate, the permit will contain the requirement that the municipal waste discharger monitor the water supply and the wastewater discharge for salinity. Such monitoring program shall be completed within 2 years and the discharger shall then present the information as specified above.

- E. Requirements for establishing incremental increases may be waived in those cases where the incremental salt load reaching the main stem of the Colorado River is less than one ton per day or 350 tons per year, whichever is less. Evaluation will be made on a case-by-case basis.
- F. All new and reissued NPDES permits for all municipalities shall require monitoring of the salinity of the intake water supply and the wastewater treatment plant effluent in accordance with the following guidelines:

<b>Treatment Plant Design Capacity</b>	<b>Monitoring Frequency</b>	<b>Type of Sample</b>
< 1.0 MGD*	Quarterly	Discrete
1.0 - 5.0 MGD	Monthly	Composite
> 5.0 - 50.0 MGD	Weekly	Composite
50.0 MGD	Daily	Composite

1. Analysis for salinity may be either as total dissolved solids (TDS) or be electrical conductivity where a satisfactory correlation with TDS has been established. The correlation should be based on a minimum of five different samples.
2. Monitoring of the intake water supply may be at a reduced frequency where the salinity of the water supply is relatively uniform.



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